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Fang et al.

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(45) **Date of Patent: Jul. 6, 2010**

(54) **DRIVER SYSTEM AND METHOD FOR MULTIPLE COLD-CATHODE FLUORESCENT LAMPS AND/OR EXTERNAL-ELECTRODE FLUORESCENT LAMPS**

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(73) Assignee: **On-Bright Electronics (Shanghai) Co., Ltd.**, Zhangjiang Hi Tech Park, Shanghai (CN)

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(22) Filed: **Oct. 15, 2007**

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(30) **Foreign Application Priority Data**

Oct. 12, 2007 (CN) 2007 1 0047024

(51) **Int. Cl.**
H05B 37/00 (2006.01)

(52) **U.S. Cl.** **315/277**; 315/278; 315/291; 315/312

(58) **Field of Classification Search** .... 315/209 R, 315/272–278, 291, 294, 307
See application file for complete search history.

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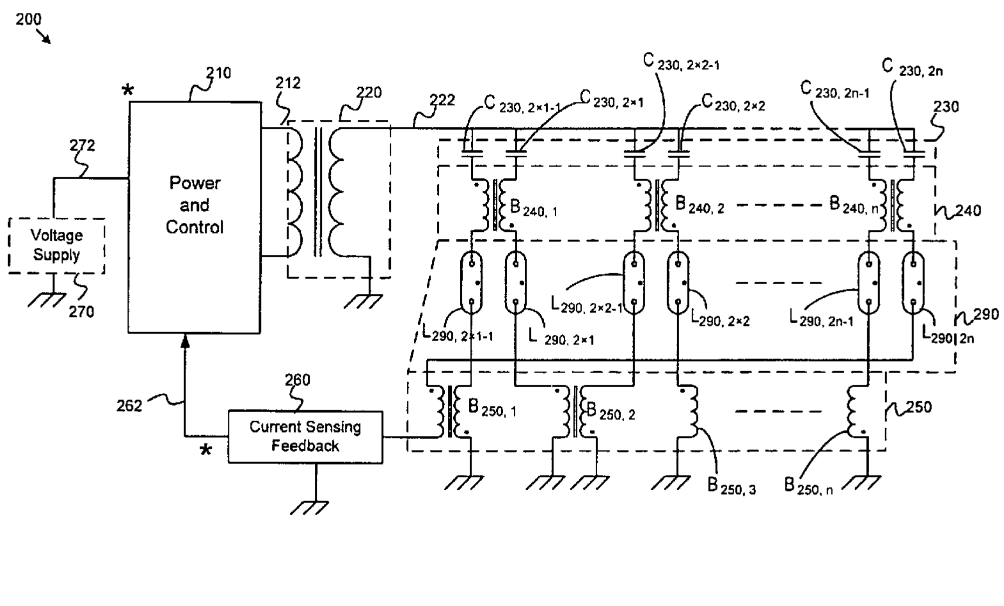
Assistant Examiner—Jimmy T Vu
(74) *Attorney, Agent, or Firm*—Jones Day

(57) **ABSTRACT**

Driver system and method for multiple cold-cathode fluorescent lamps and/or external-electrode fluorescent lamps. According to an embodiment, the present invention provides a system for driving a plurality of cold-cathode fluorescent lamps. The system includes a subsystem configured to receive at least a DC voltage and generate a first AC voltage in response to at least the DC voltage. The system also includes a power converter configured to receive the first AC voltage and convert the first AC voltage to at least a second AC voltage. The system further includes a plurality of current balancing devices. Each of the plurality of current balancing devices is configured to receive two currents and balance the two currents. The plurality of current balancing devices includes at least a first current balancing device, a second current balancing device, and a third current balancing device. In addition, the system includes a plurality of lamp pairs.

33 Claims, 23 Drawing Sheets



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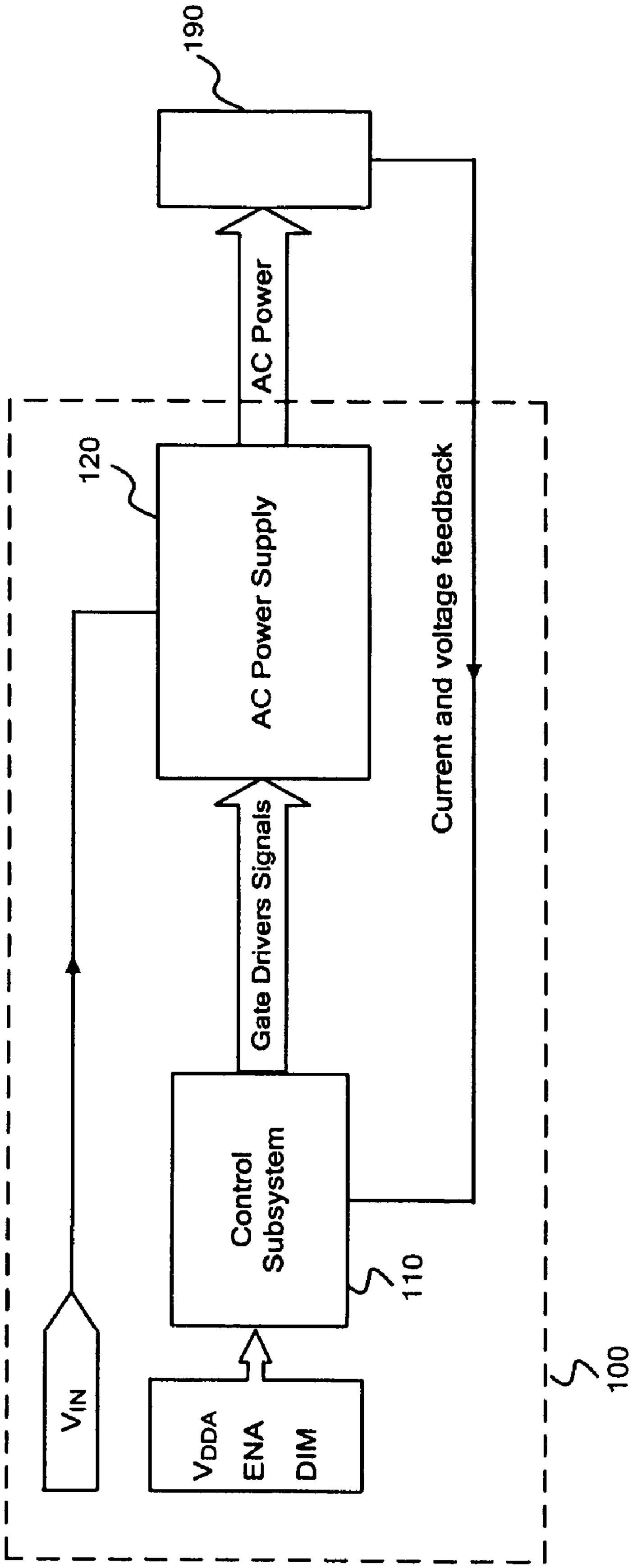

190
AC Power
120
AC Power Supply
Current and voltage feedback
Gate Drivers Signals
Control Subsystem
110
V_{IN}
V_{DDA}
ENA
DIM
100

FIG. 1

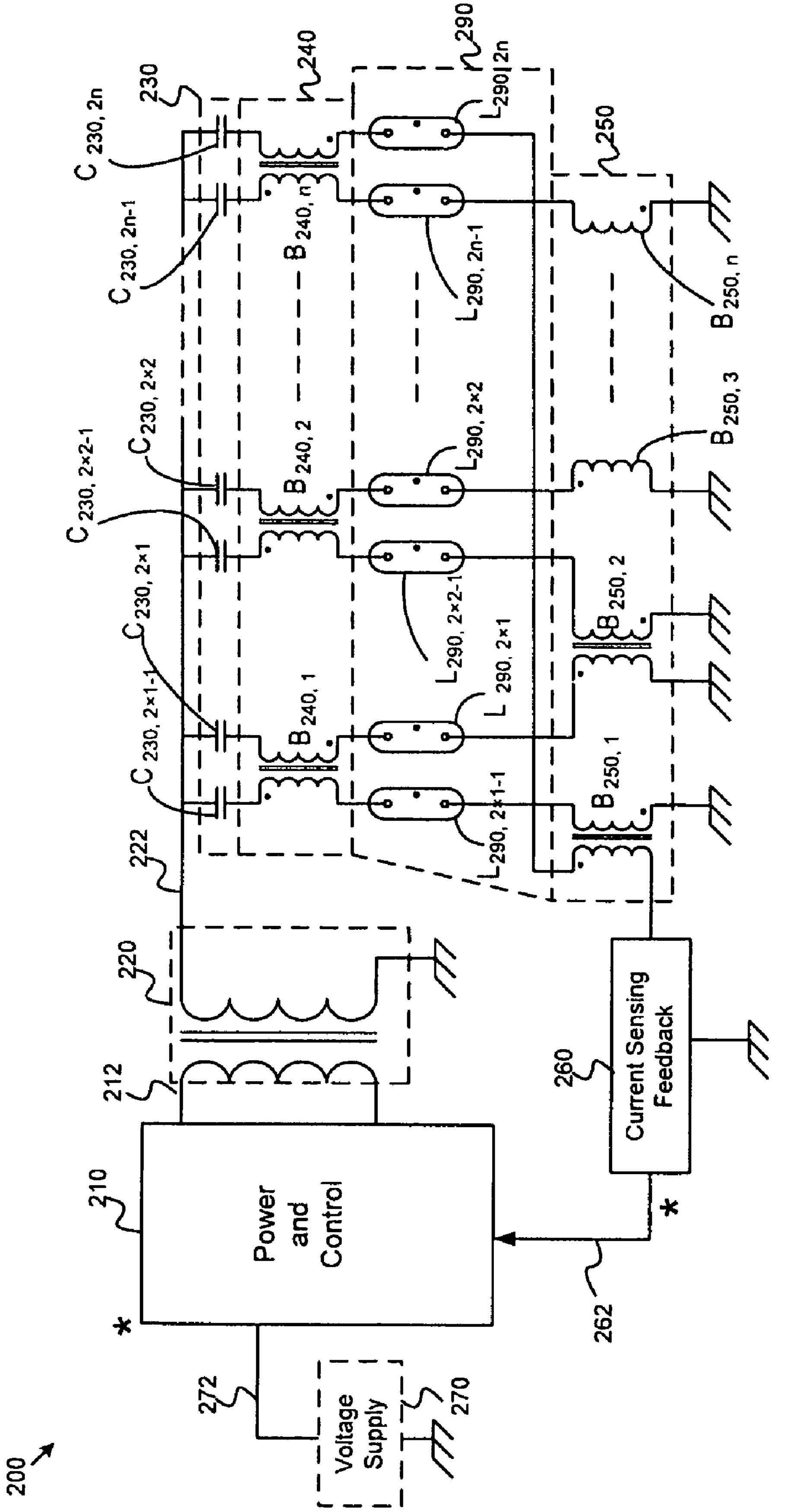

200
Voltage Supply
270
272
Power and Control
210
212
220
222
Current Sensing Feedback
260
262
230
240
250
290
$C_{230, 2n}$
$C_{230, 2n-1}$
$C_{230, 2\times2}$
$C_{230, 2\times2-1}$
$C_{230, 2\times1}$
$C_{230, 2\times1-1}$
$B_{240, n}$
$B_{240, 2}$
$B_{240, 1}$
$L_{290, 2n}$
$L_{290, 2n-1}$
$L_{290, 2\times2}$
$L_{290, 2\times2-1}$
$L_{290, 2\times1}$
$L_{290, 2\times1-1}$
$B_{250, n}$
$B_{250, 3}$
$B_{250, 2}$
$B_{250, 1}$

FIG. 2

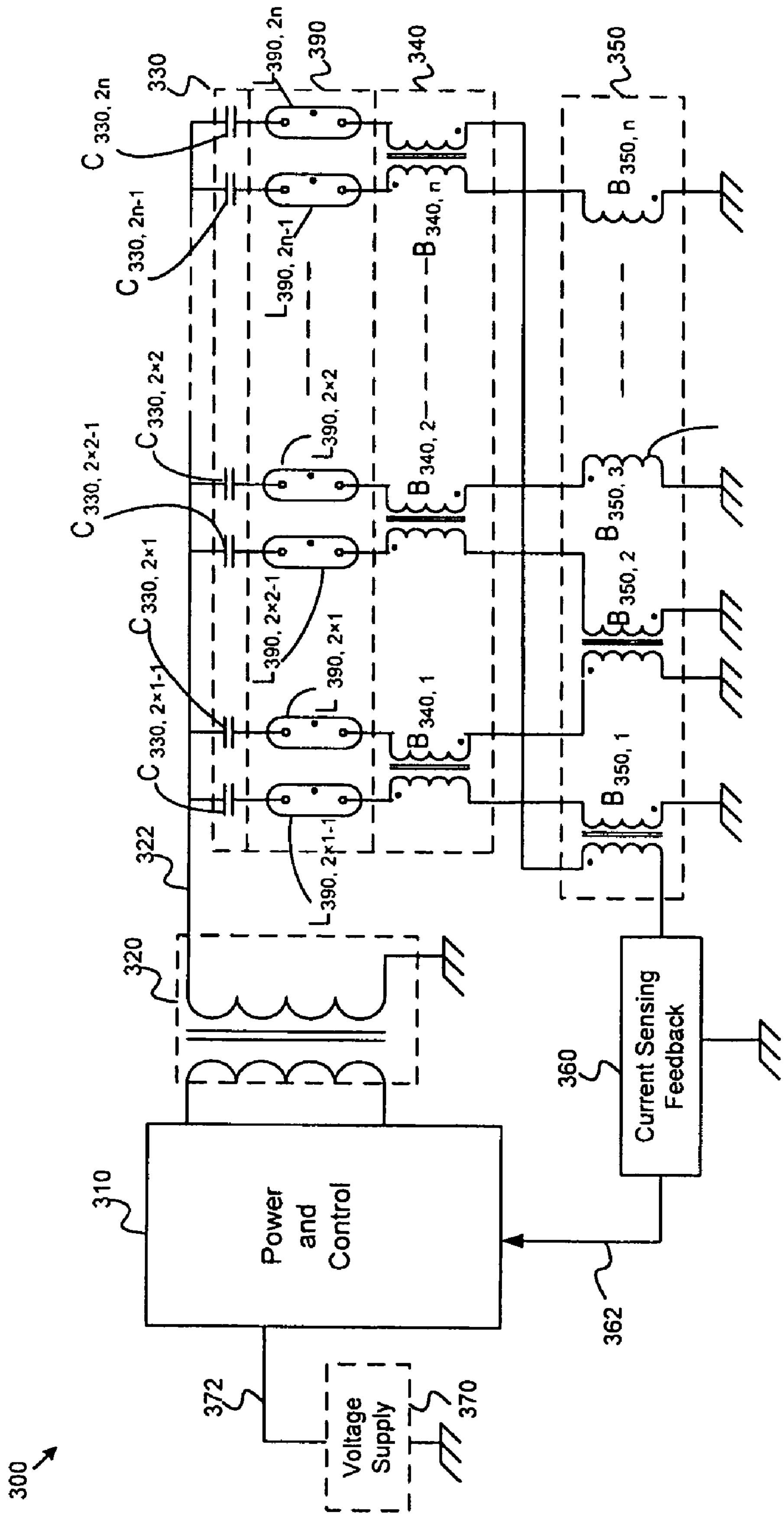

300
310
Power and Control
320
322
330
390
340
350
360
Current Sensing Feedback
362
370
Voltage Supply
372
$C_{330, 2n}$
$C_{330, 2n-1}$
$C_{330, 2×2}$
$C_{330, 2×2-1}$
$C_{330, 2×1}$
$C_{330, 2×1-1}$
$L_{390, 2n}$
$L_{390, 2n-1}$
$L_{390, 2×2}$
$L_{390, 2×2-1}$
$L_{390, 2×1}$
$L_{390, 2×1-1}$
$B_{340, n}$
$B_{340, 2}$
$B_{340, 1}$
$B_{350, n}$
$B_{350, 3}$
$B_{350, 2}$
$B_{350, 1}$

FIG. 3

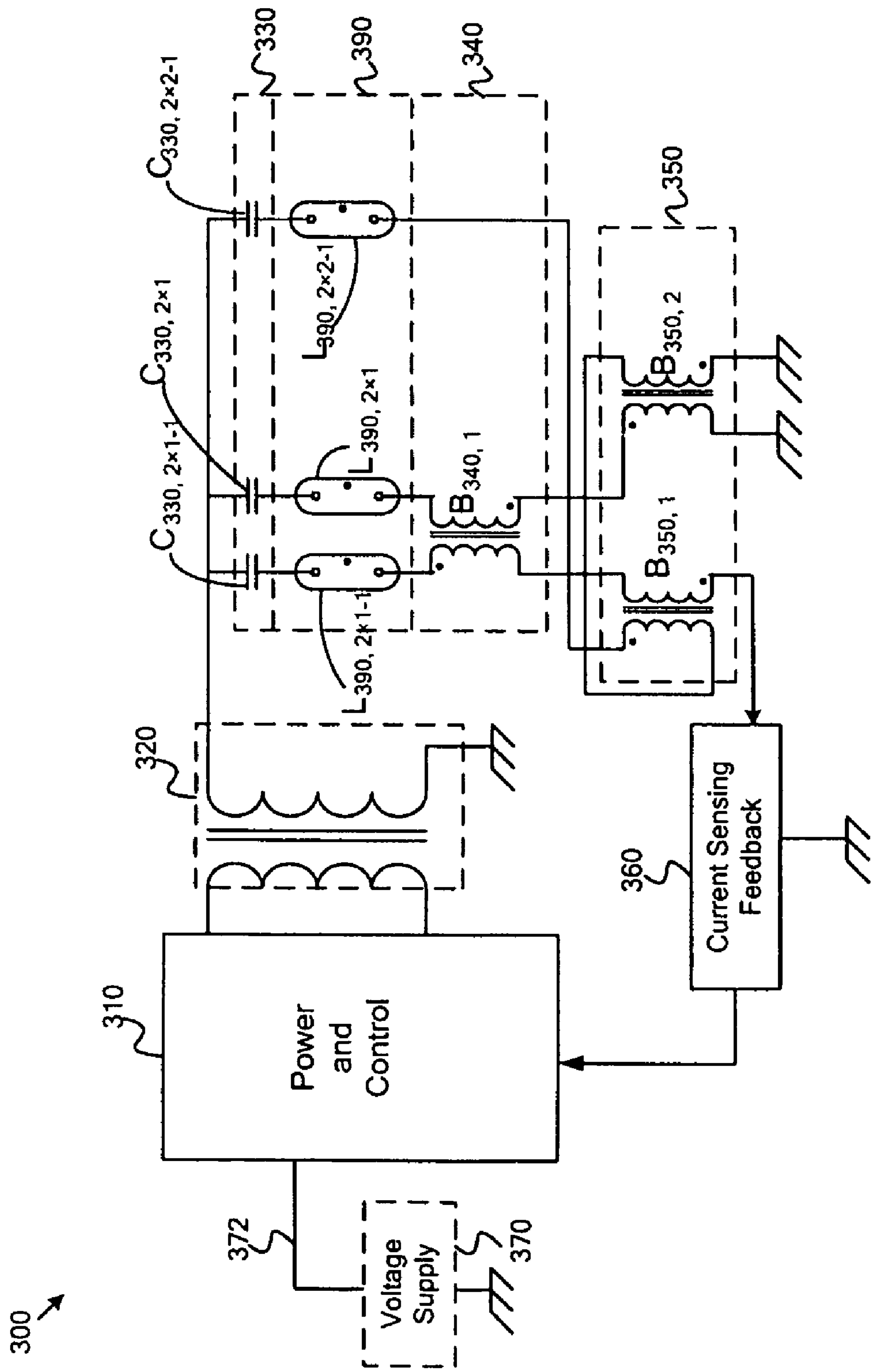

300
310
Power and Control
320
330
390
340
350
360
Current Sensing Feedback
370
372
Voltage Supply
$C_{330,\ 2\times2\text{-}1}$
$C_{330,\ 2\times1}$
$C_{330,\ 2\times1\text{-}1}$
$L_{390,\ 2\times2\text{-}1}$
$L_{390,\ 2\times1}$
$L_{390,\ 2\times1\text{-}1}$
$B_{340,\ 1}$
$B_{350,\ 1}$
$B_{350,\ 2}$

FIG. 4

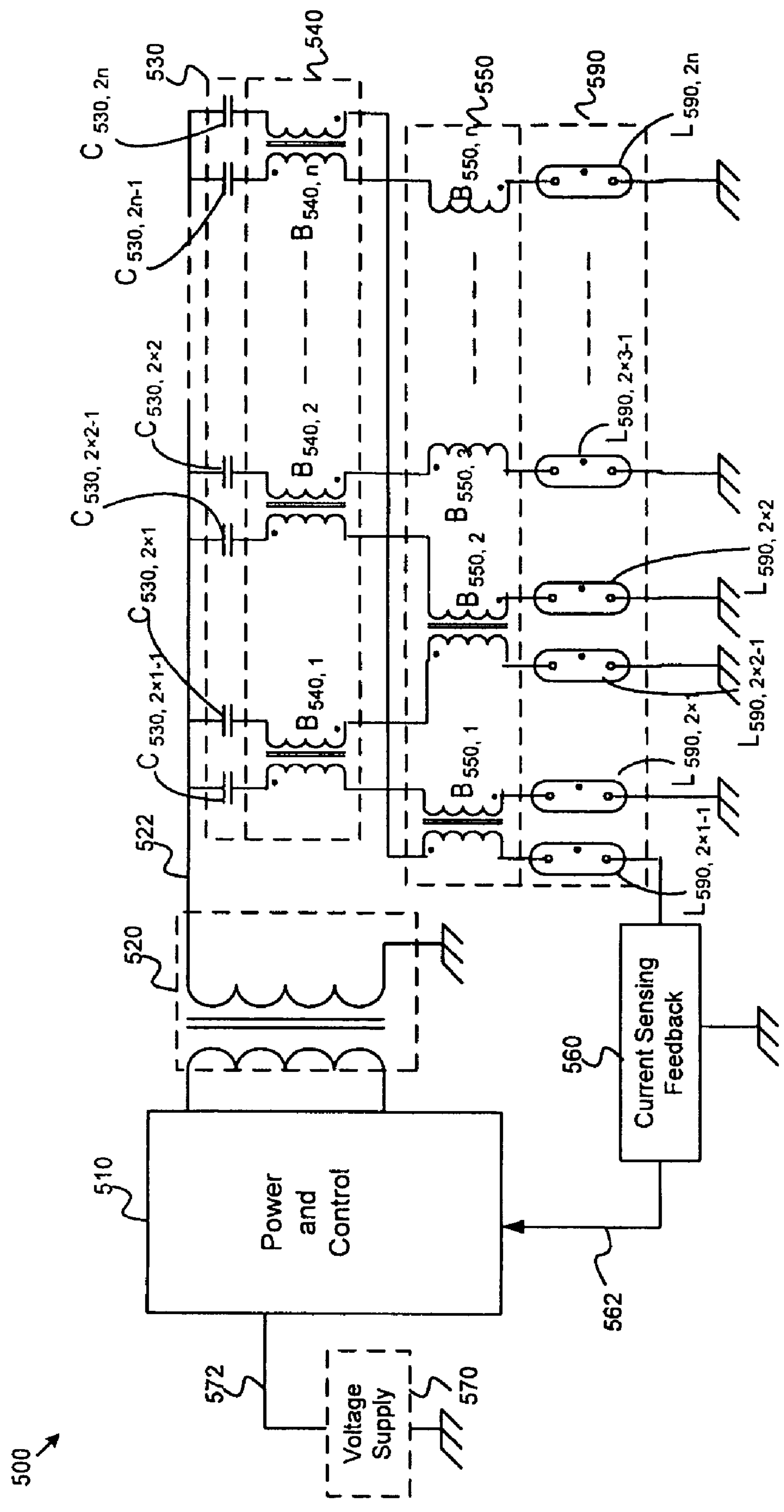

500
510
Power and Control
520
522
530
540
550
560
Current Sensing Feedback
562
570
Voltage Supply
572
590
C 530, 2×1-1
C 530, 2×1
C 530, 2×2-1
C 530, 2×2
C 530, 2n-1
C 530, 2n
B 540, 1
B 540, 2
B 540, n
B 550, 1
B 550, 2
B 550, 3
B 550, n
L 590, 2×1-1
L 590, 2×1
L 590, 2×2-1
L 590, 2×2
L 590, 2×3-1
L 590, 2n

FIG. 5

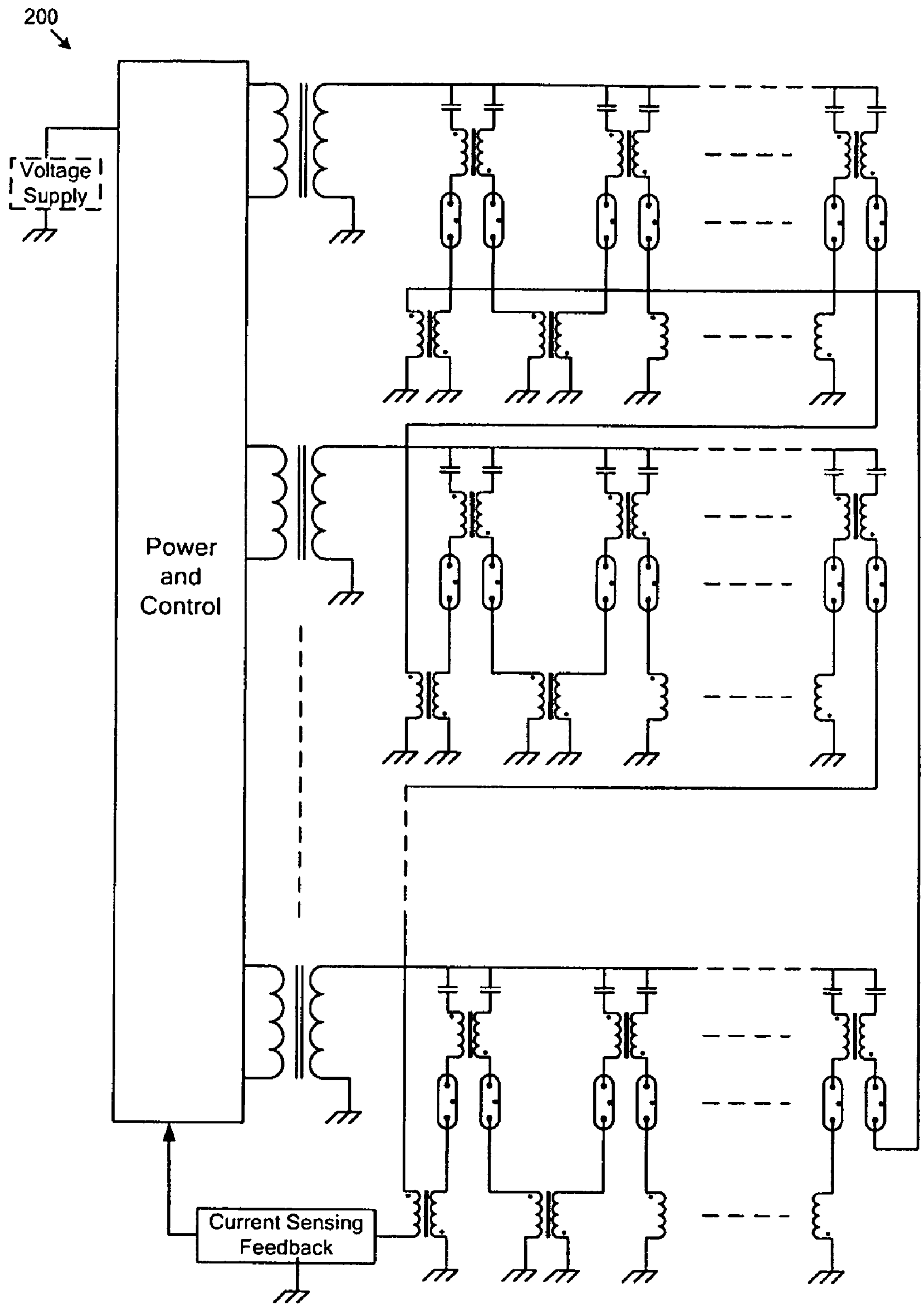

200
Voltage Supply
Power and Control
Current Sensing Feedback

FIG. 6

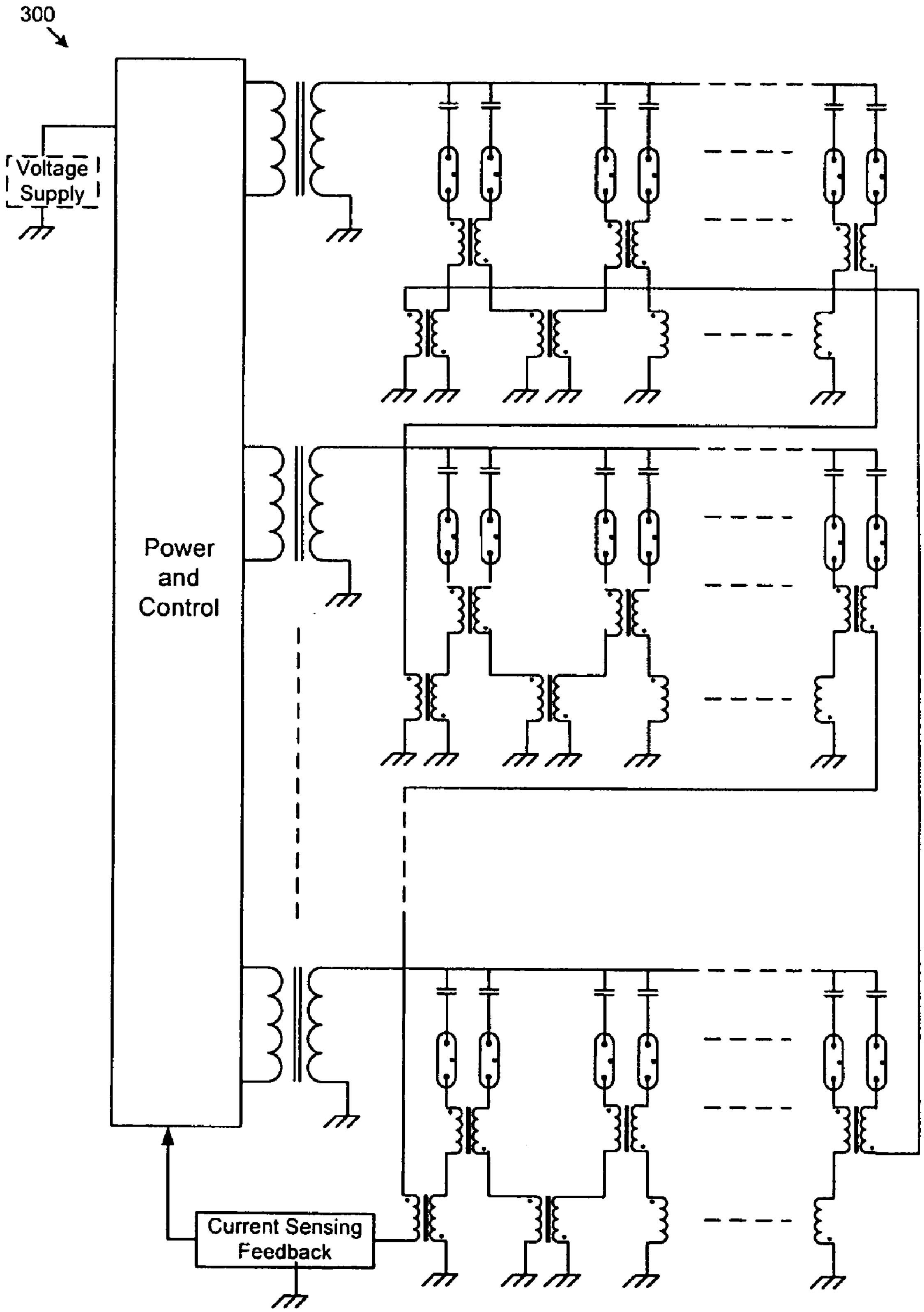

300
Voltage Supply
Power and Control
Current Sensing Feedback

FIG. 7

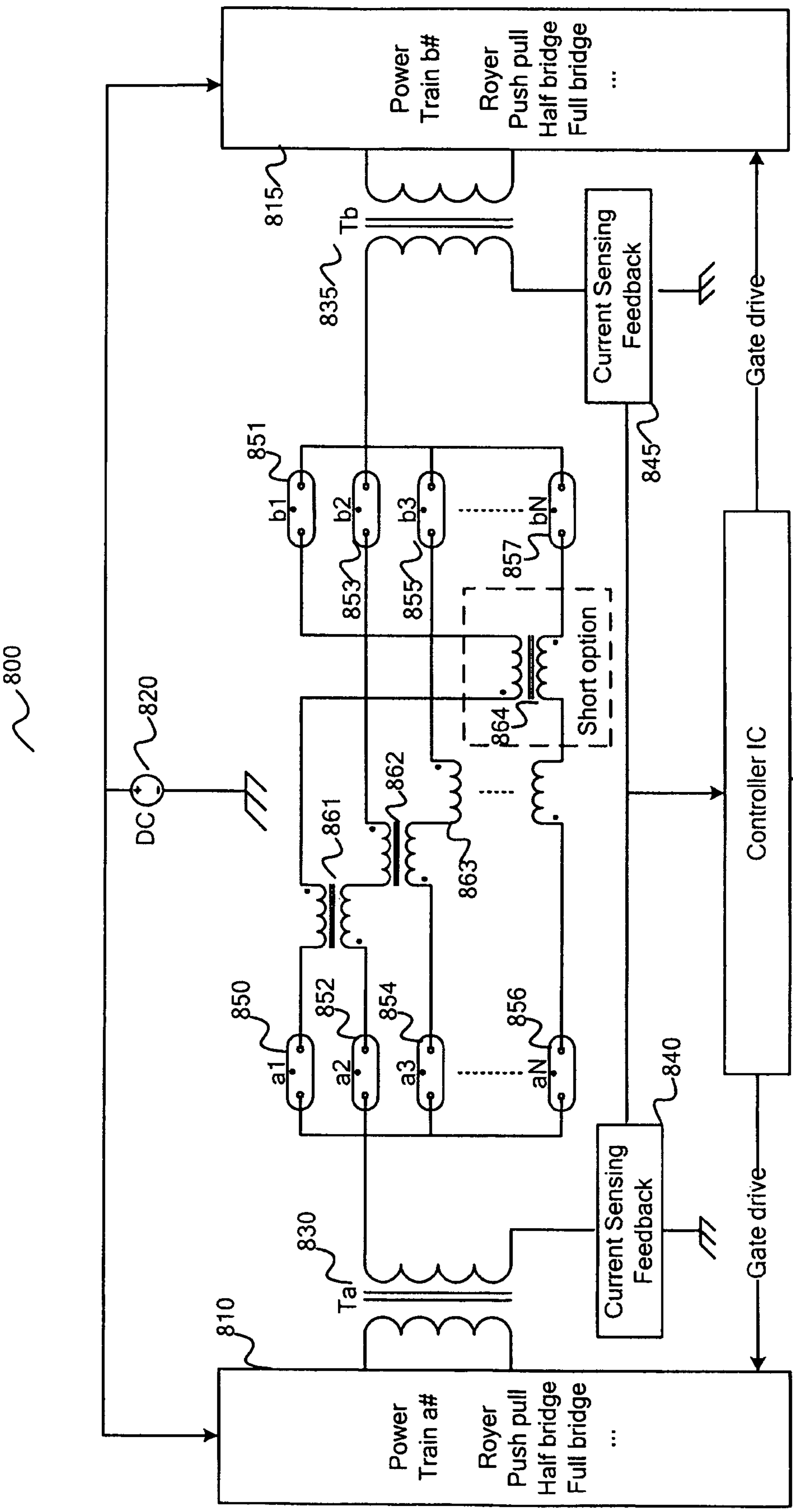

800
Power Train b#
Royer
Push pull
Half bridge
Full bridge
...
815
Tb
835
Current Sensing Feedback
845
Gate drive
b1
851
b2
853
b3
855
bN
857
Short option
864
DC
820
861
862
863
a1
850
a2
852
a3
854
aN
856
Controller IC
805
840
Current Sensing Feedback
Gate drive
830
Ta
810
Power Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 8

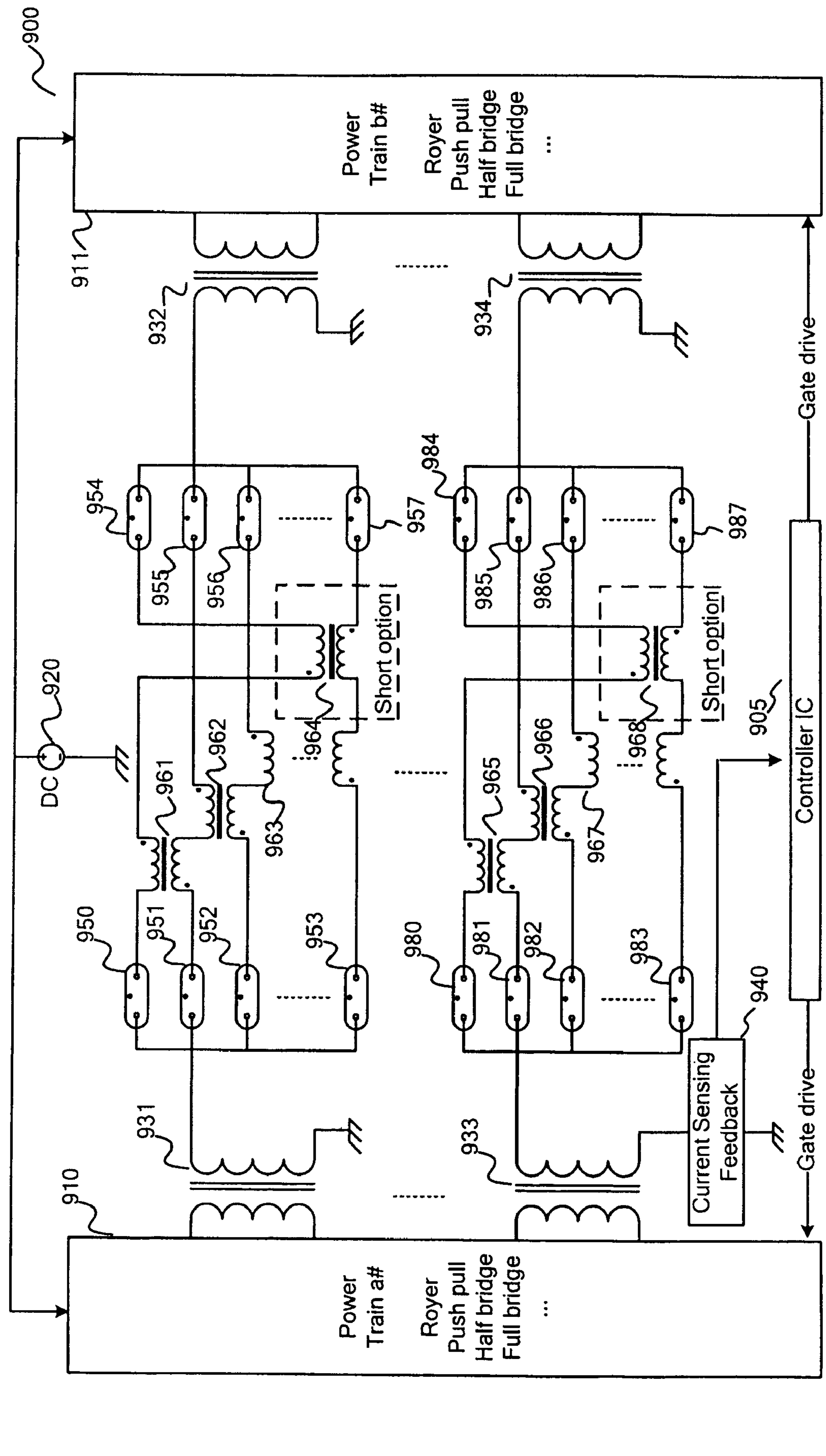

900
Power Train b#
Royer
Push pull
Half bridge
Full bridge
...
911
932
934
954
955
956
957
984
985
986
987
Short option
Short option
920
DC
961
962
963
964
965
966
967
968
905
Controller IC
950
951
952
953
980
981
982
983
940
Current Sensing Feedback
931
933
910
Gate drive
Gate drive
Power Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 9

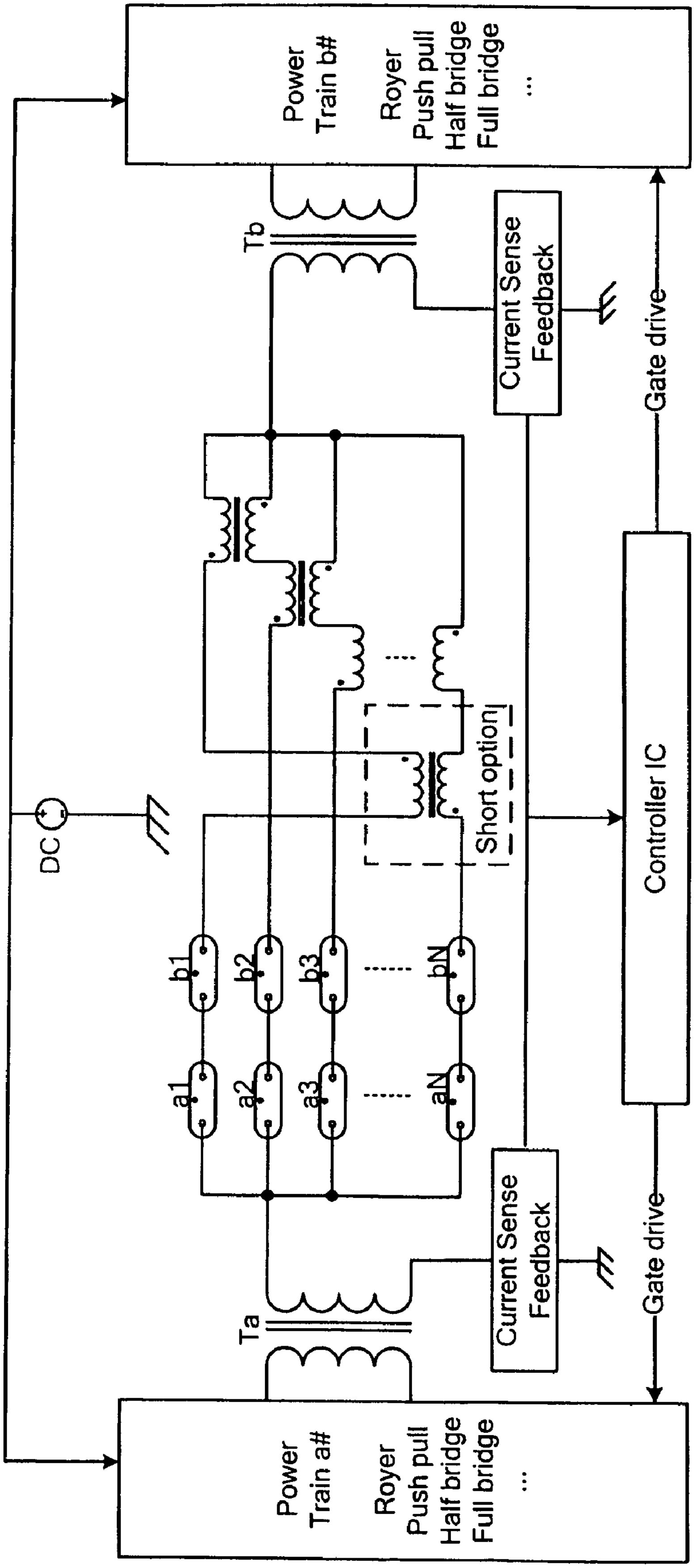

Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
Tb
Current Sense
Feedback
Gate drive
DC
Short option
Controller IC
b1
b2
b3
bN
a1
a2
a3
aN
Current Sense
Feedback
Gate drive
Ta
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 10

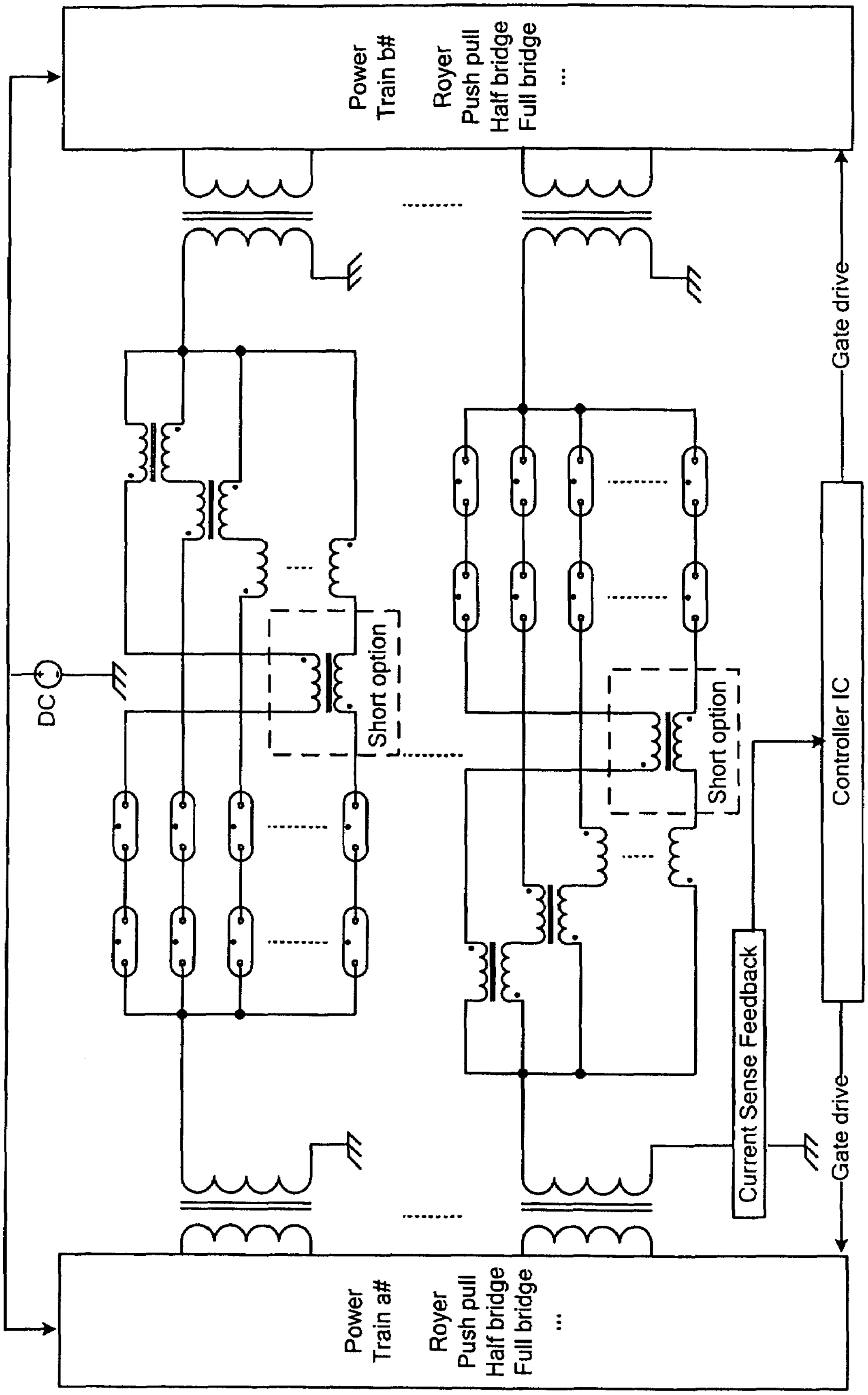

Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
Gate drive
DC
Short option
Short option
Controller IC
Current Sense Feedback
Gate drive
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 11

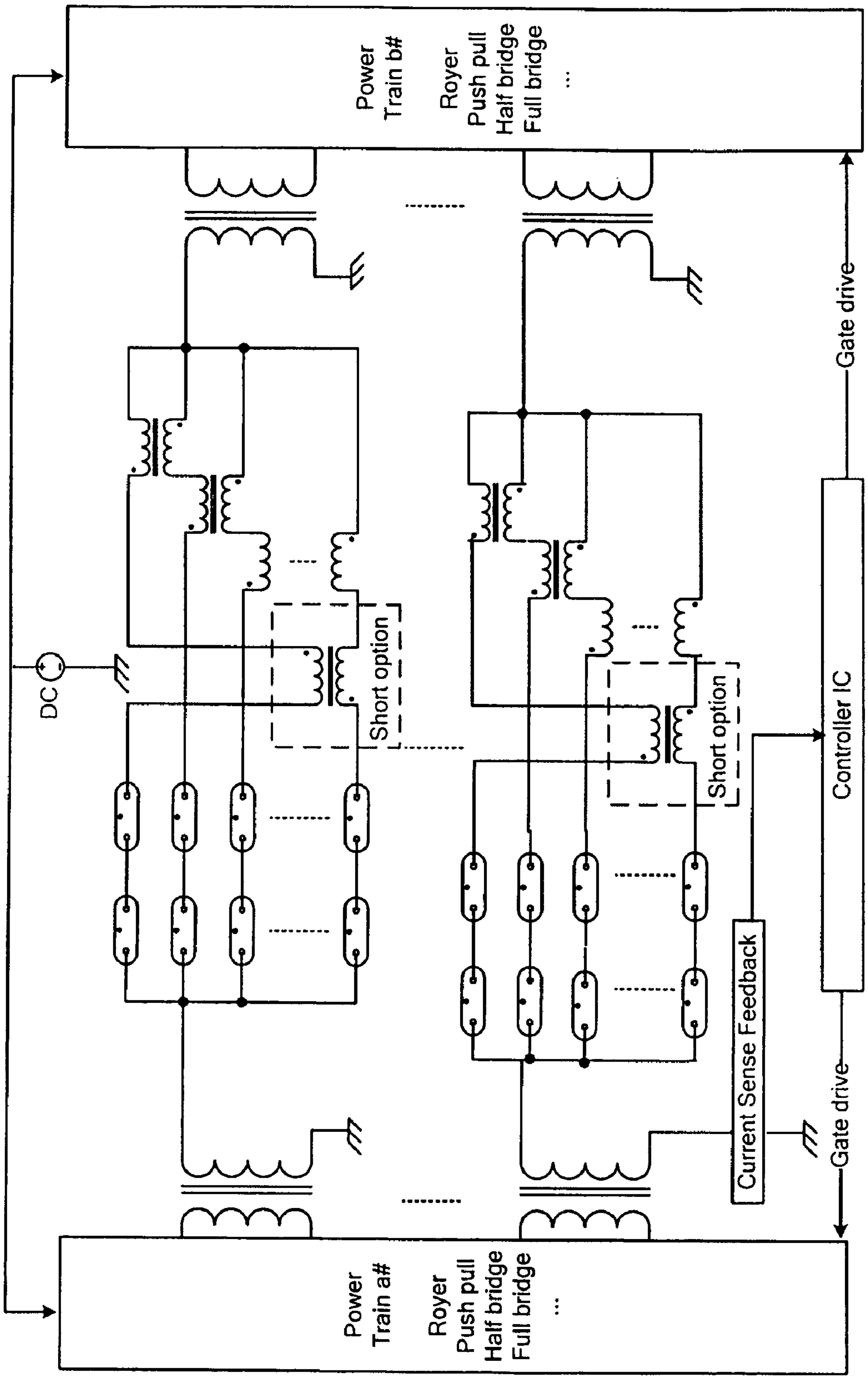

Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
DC
Short option
Short option
Gate drive
Controller IC
Current Sense Feedback
Gate drive
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 12

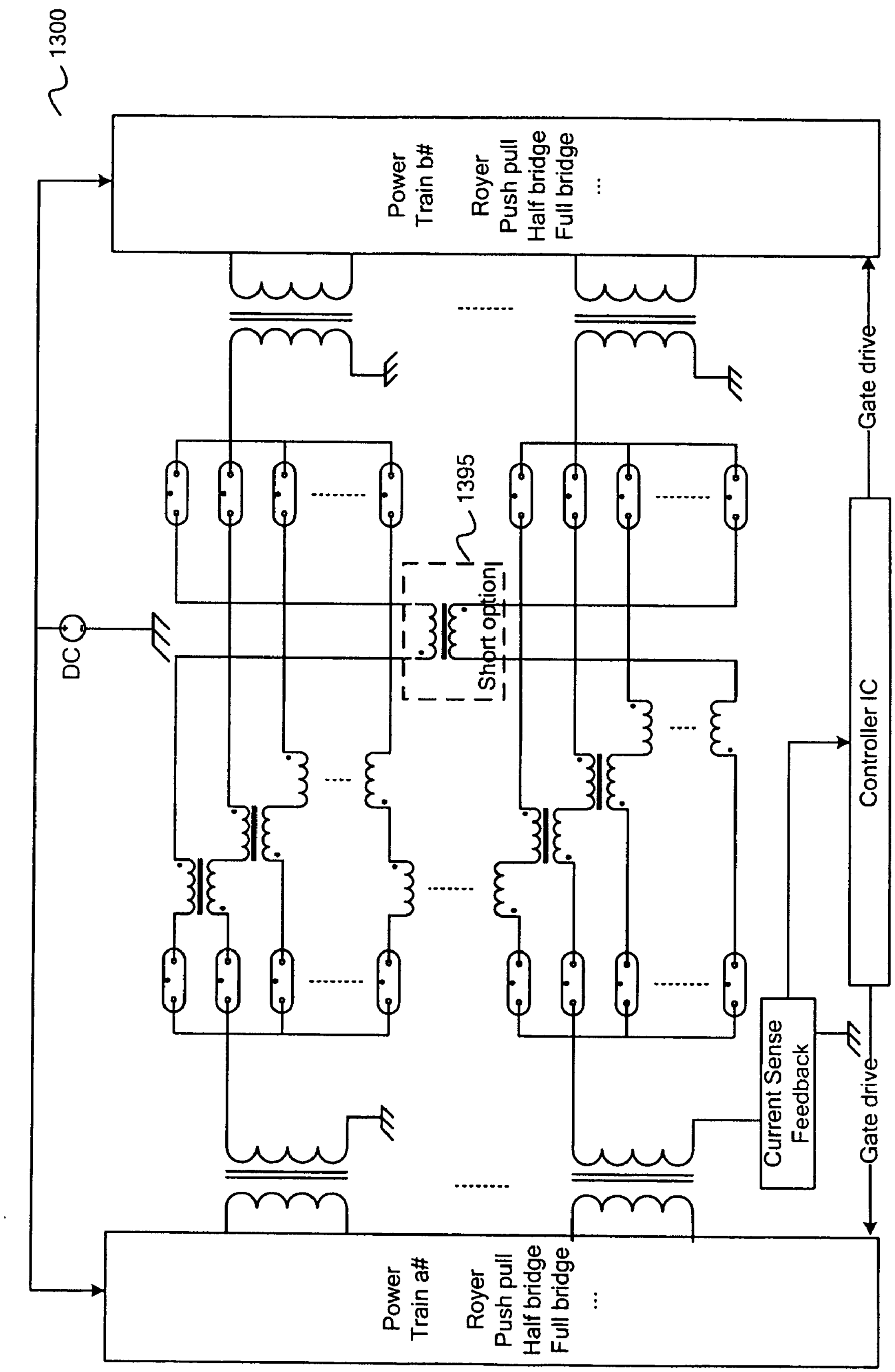
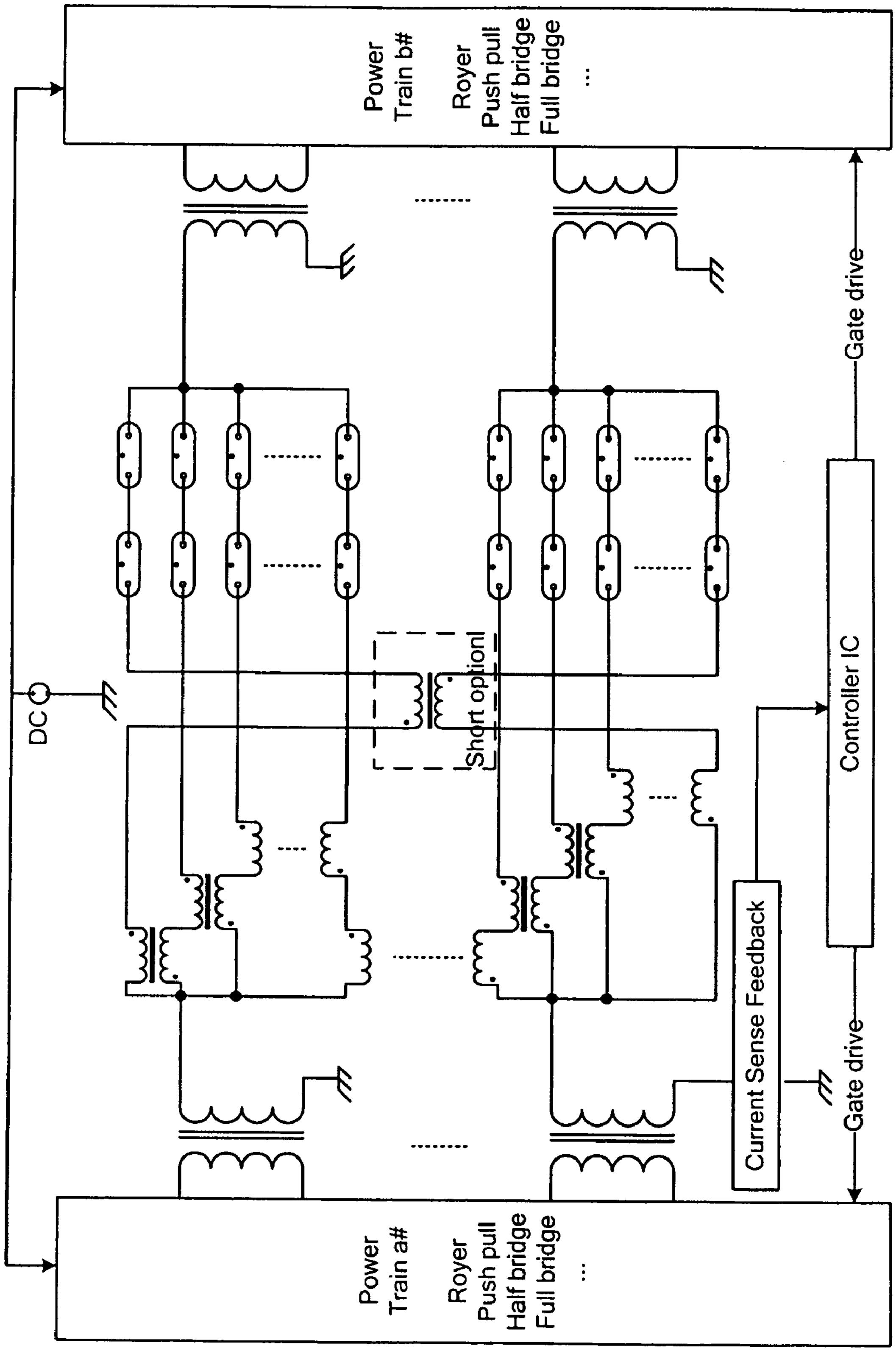

1300
Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
DC
1395
Short option
Gate drive
Controller IC
Current Sense
Feedback
Gate drive
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 13



Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
Gate drive
DC
Short option
Controller IC
Current Sense Feedback
Gate drive
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 14

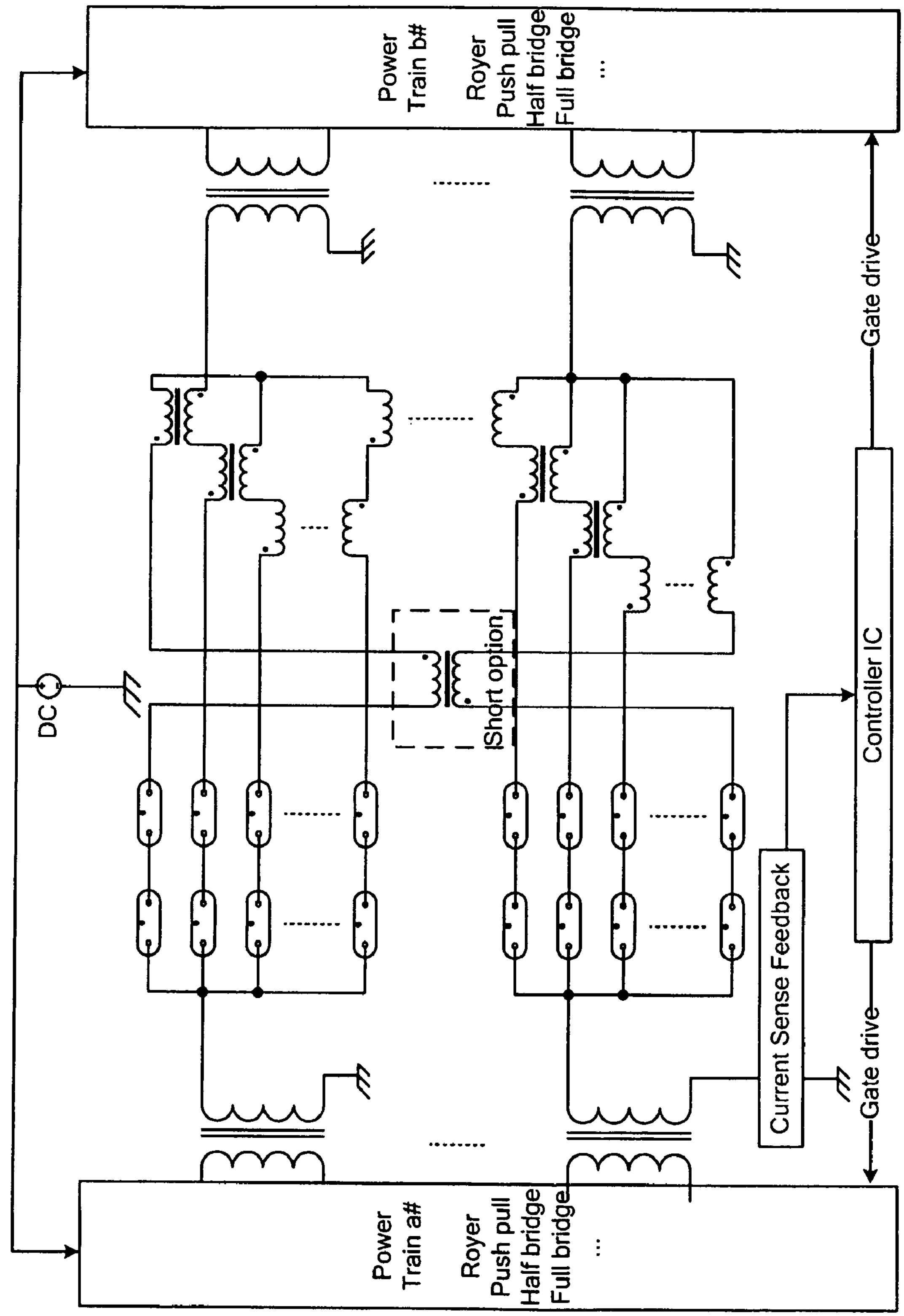
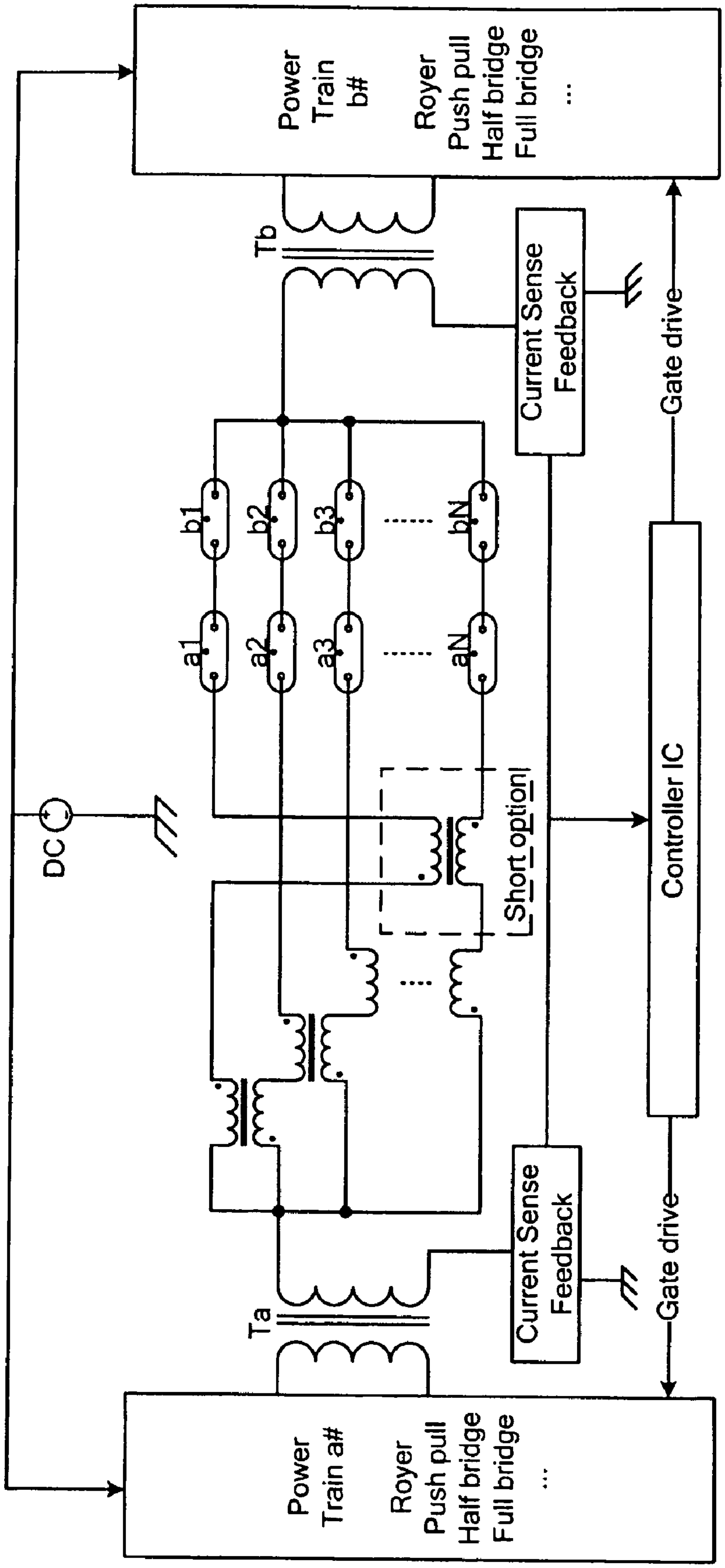

Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
Gate drive
DC
Short option
Controller IC
Current Sense Feedback
Gate drive
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 15



Power
Train
b#
Royer
Push pull
Half bridge
Full bridge
...
Tb
Current Sense
Feedback
Gate drive
b1
b2
b3
bN
a1
a2
a3
aN
DC
Short option
Controller IC
Current Sense
Feedback
Gate drive
Ta
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 16

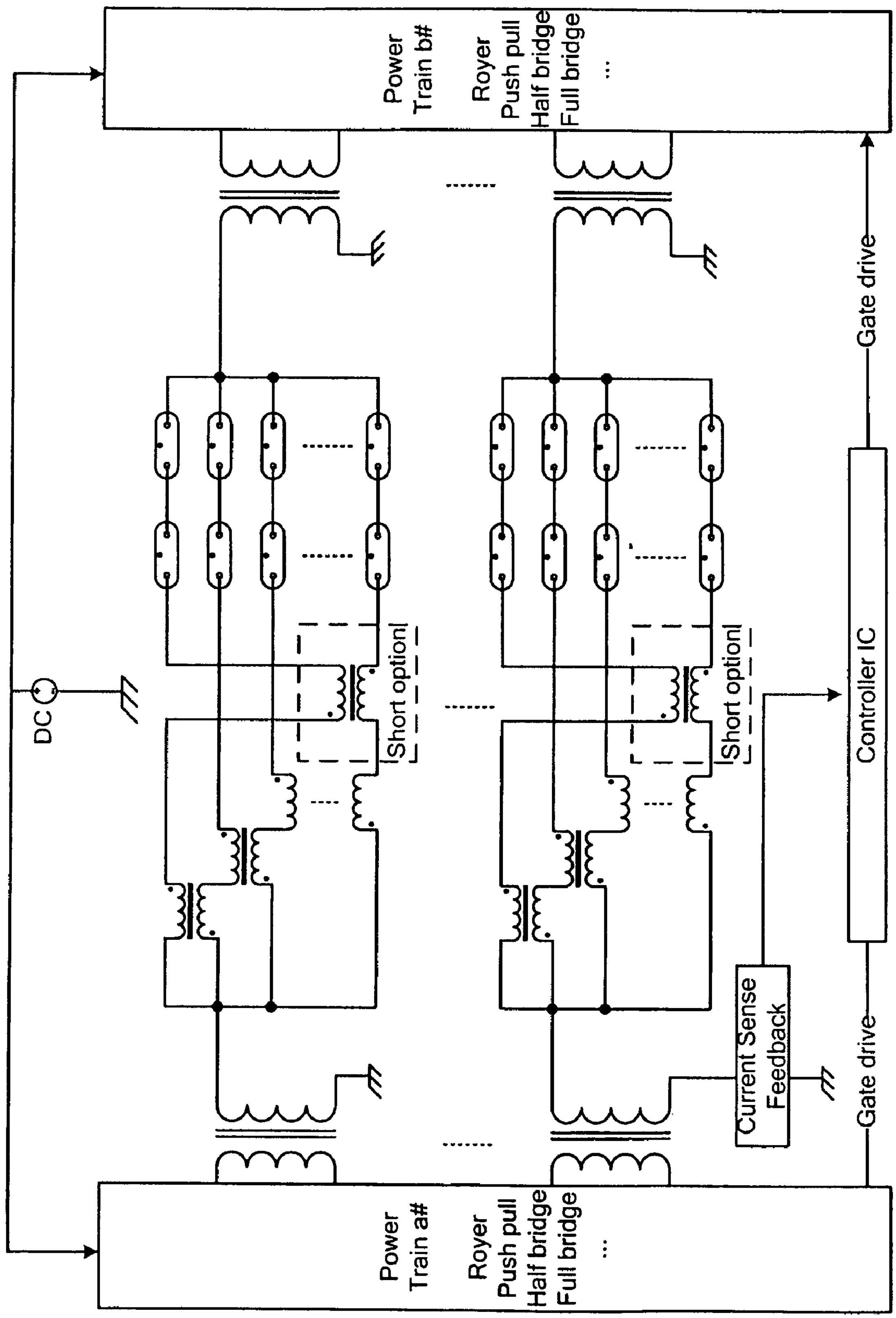
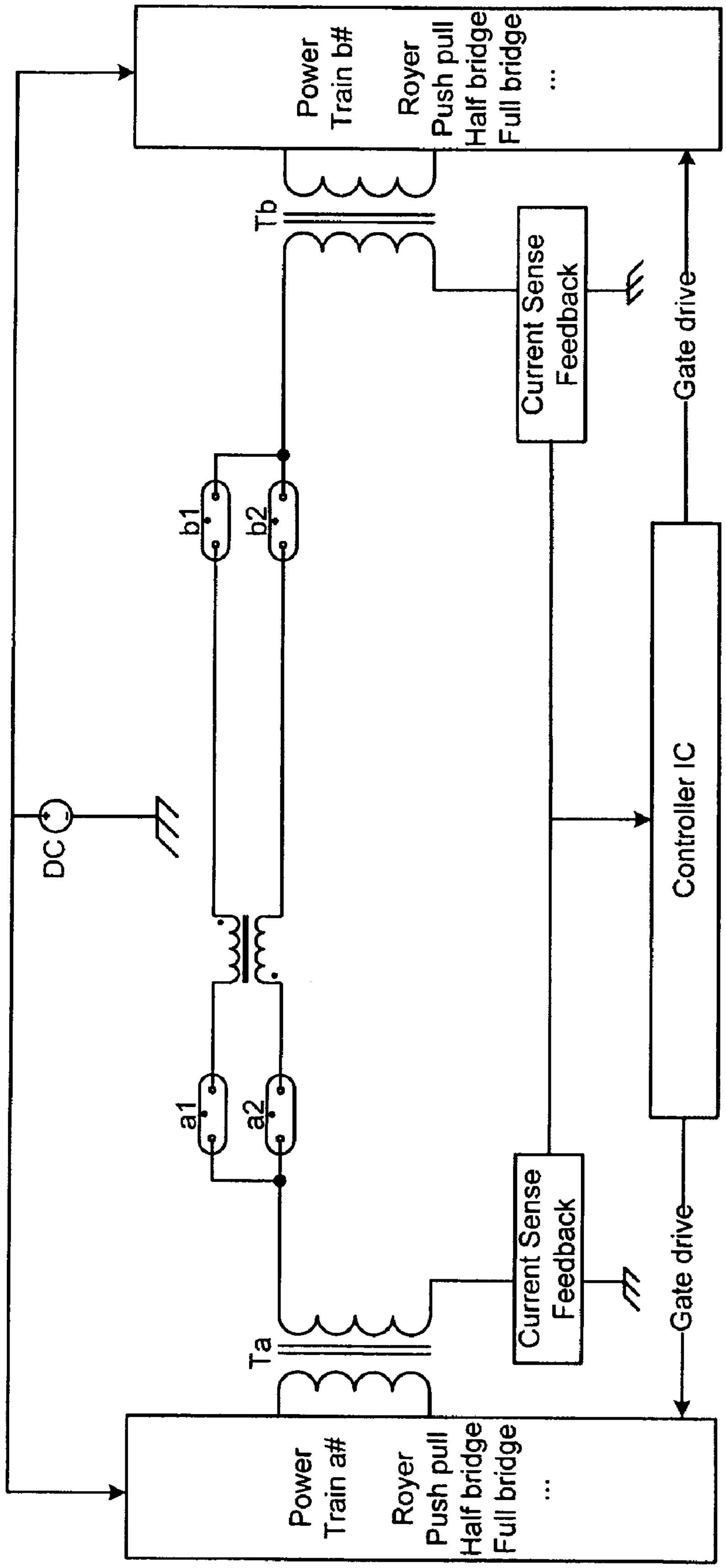

Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
DC
Short option
Short option
Gate drive
Controller IC
Current Sense
Feedback
Gate drive
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 17



Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
Tb
Current Sense
Feedback
Gate drive
b1
b2
DC
Controller IC
a1
a2
Current Sense
Feedback
Gate drive
Ta
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 18

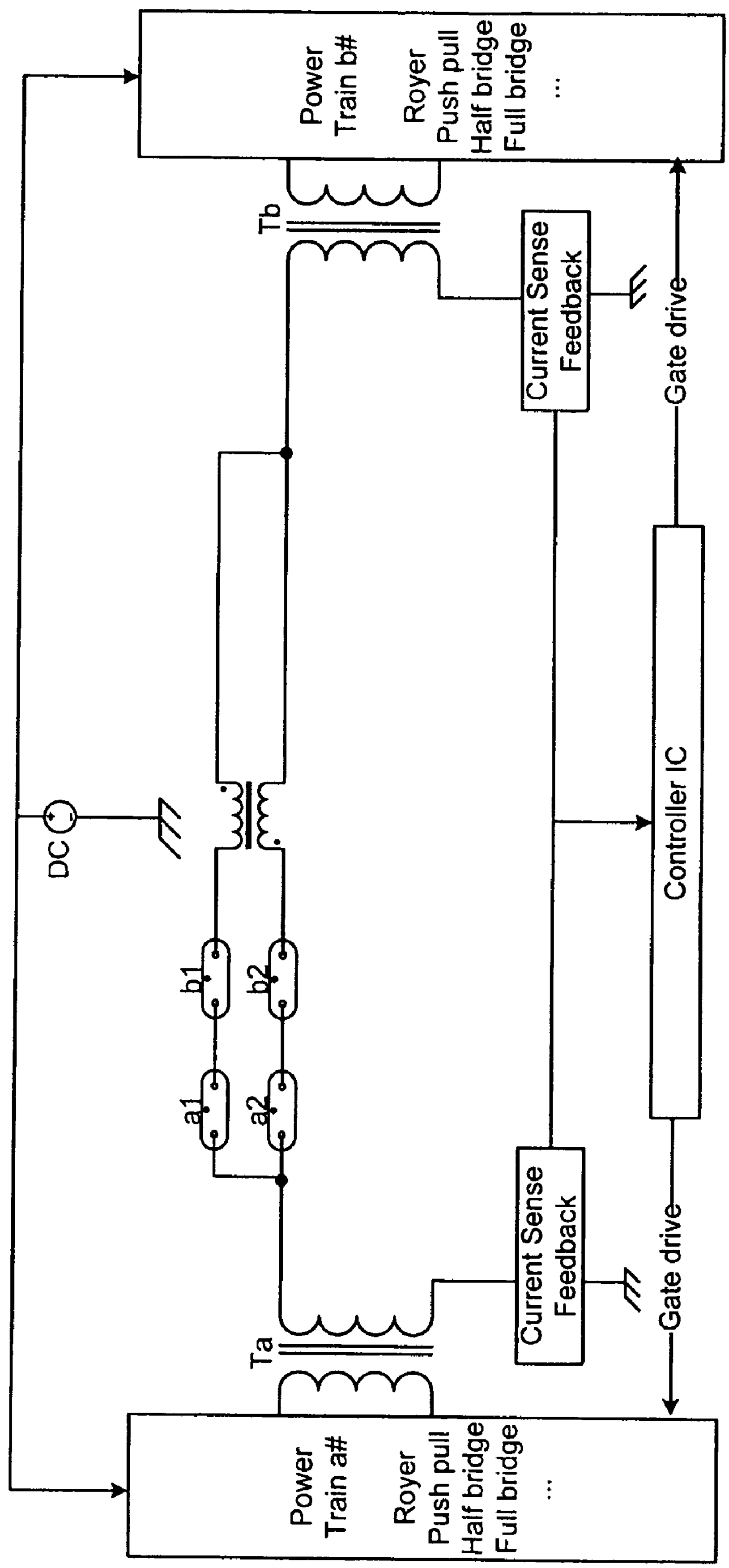

Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
Tb
Current Sense
Feedback
Gate drive
DC
b1
b2
a1
a2
Controller IC
Current Sense
Feedback
Gate drive
Ta
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 19

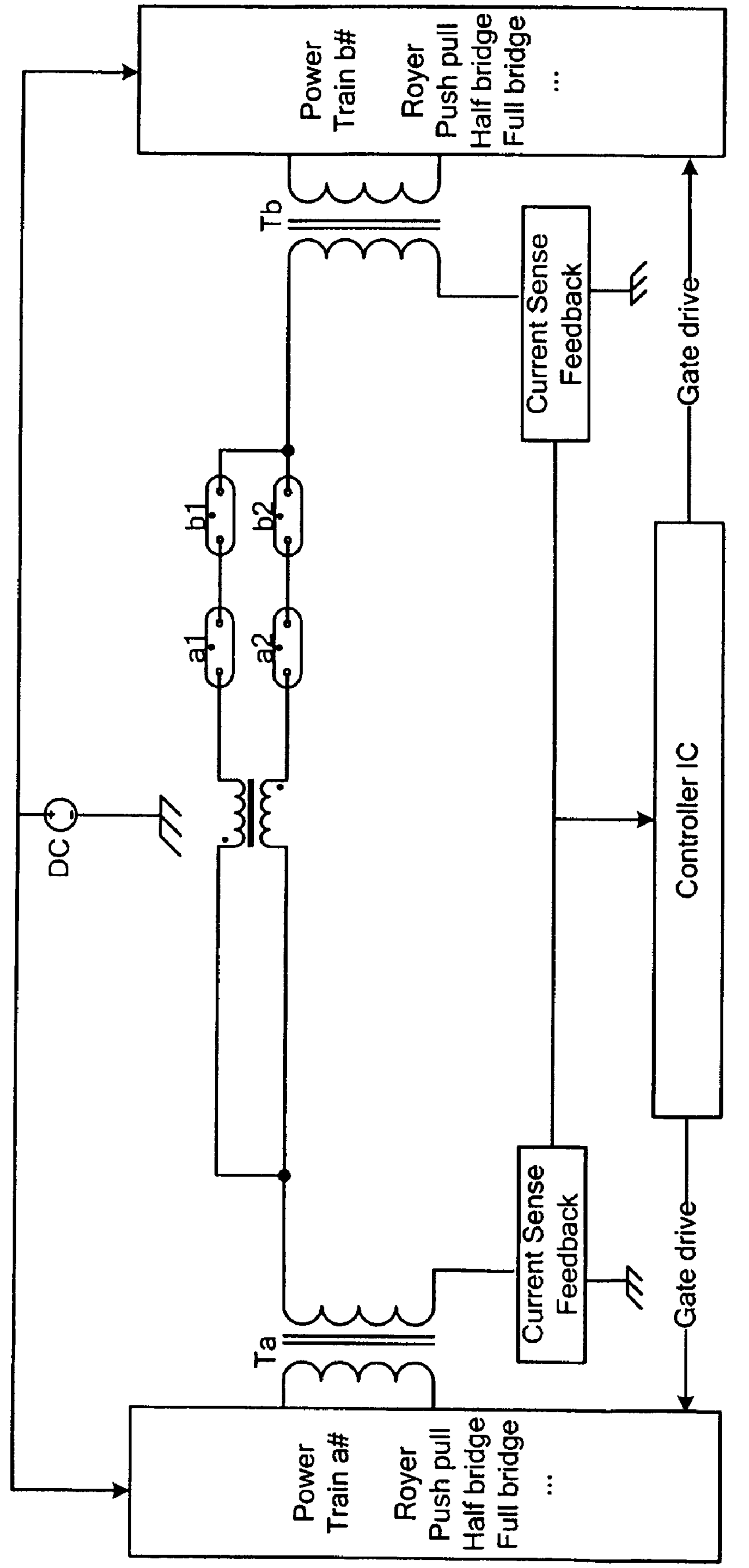

Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
Tb
Current Sense
Feedback
Gate drive
b1
b2
a1
a2
DC
Controller IC
Current Sense
Feedback
Gate drive
Ta
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 20

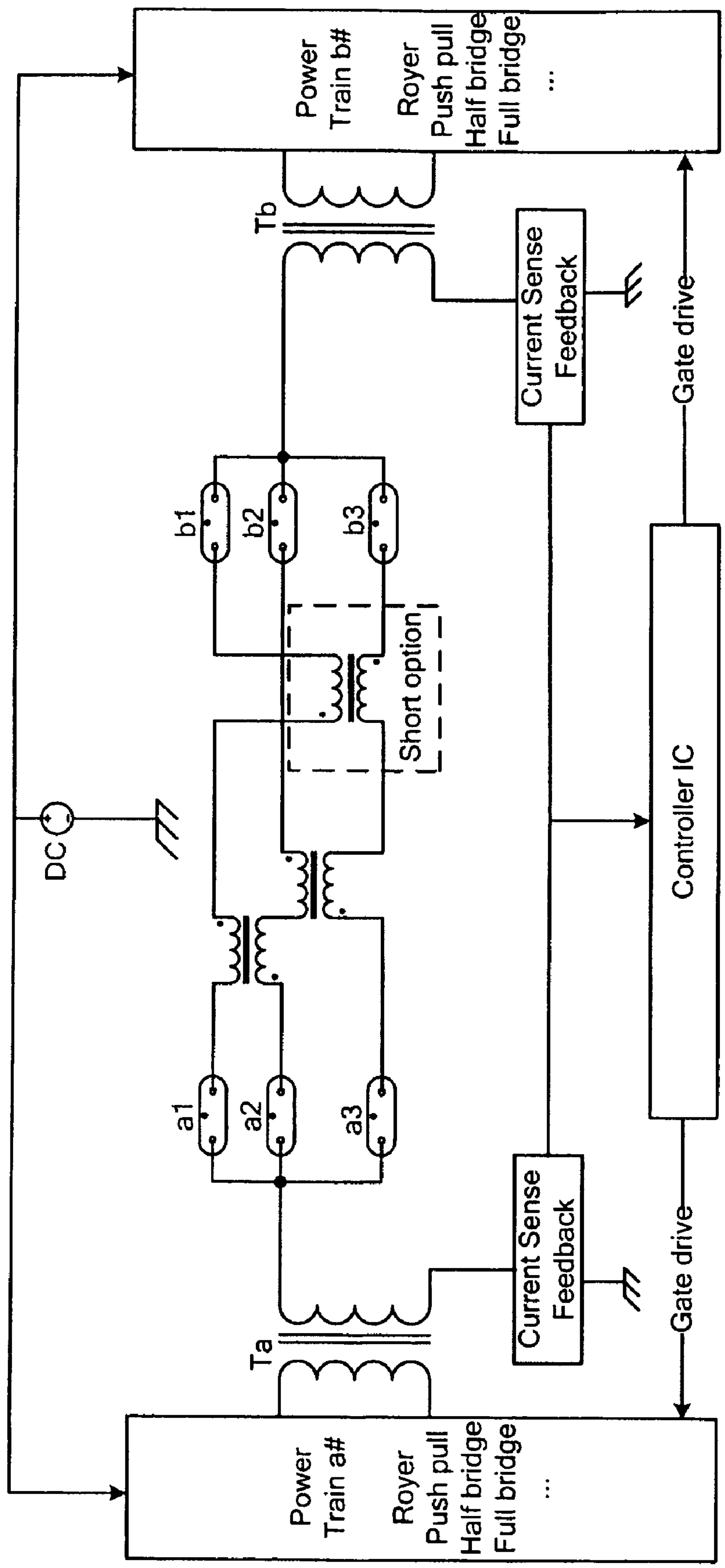

Power Train b#
Royer
Push pull
Half bridge
Full bridge
...
Tb
b1
b2
b3
Short option
DC
a1
a2
a3
Ta
Current Sense Feedback
Current Sense Feedback
Gate drive
Gate drive
Controller IC
Power Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 21

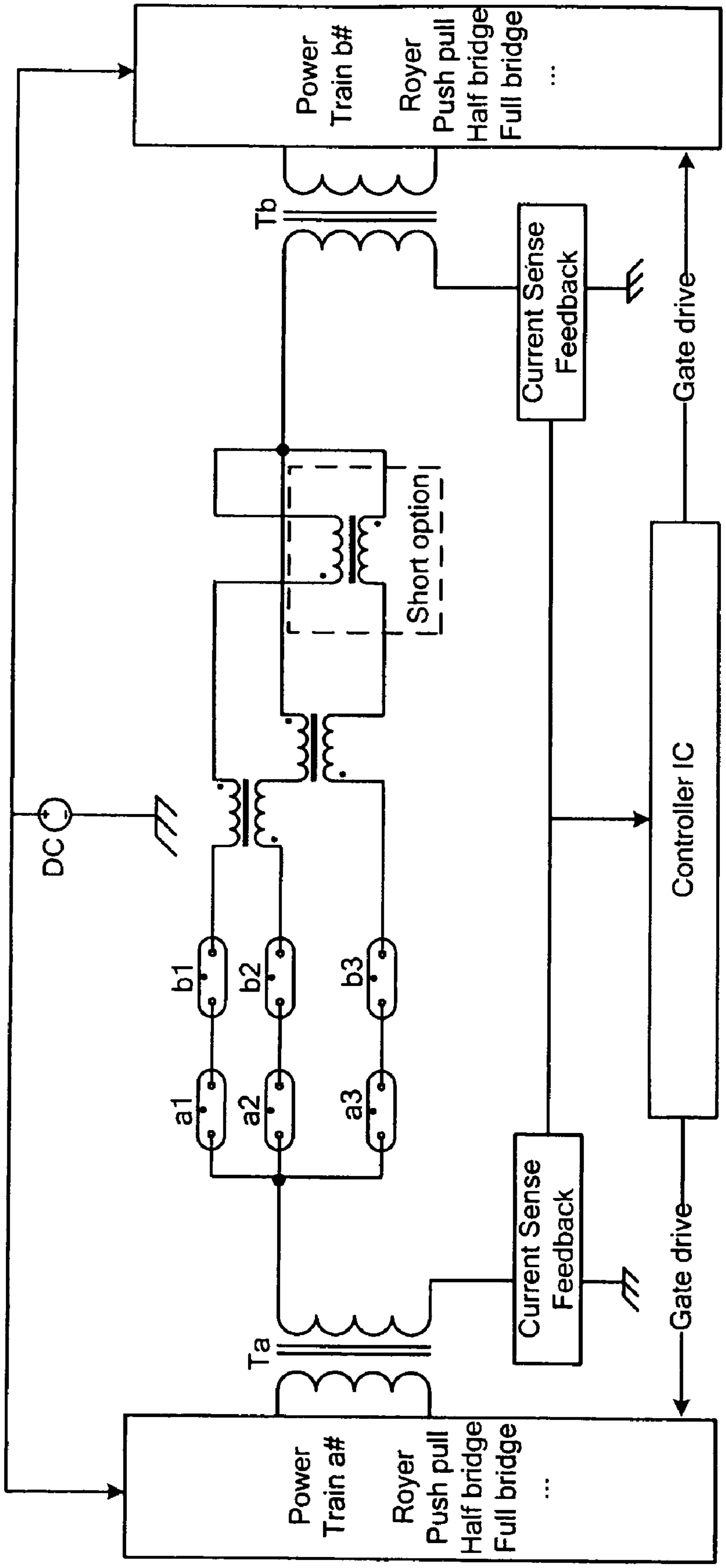
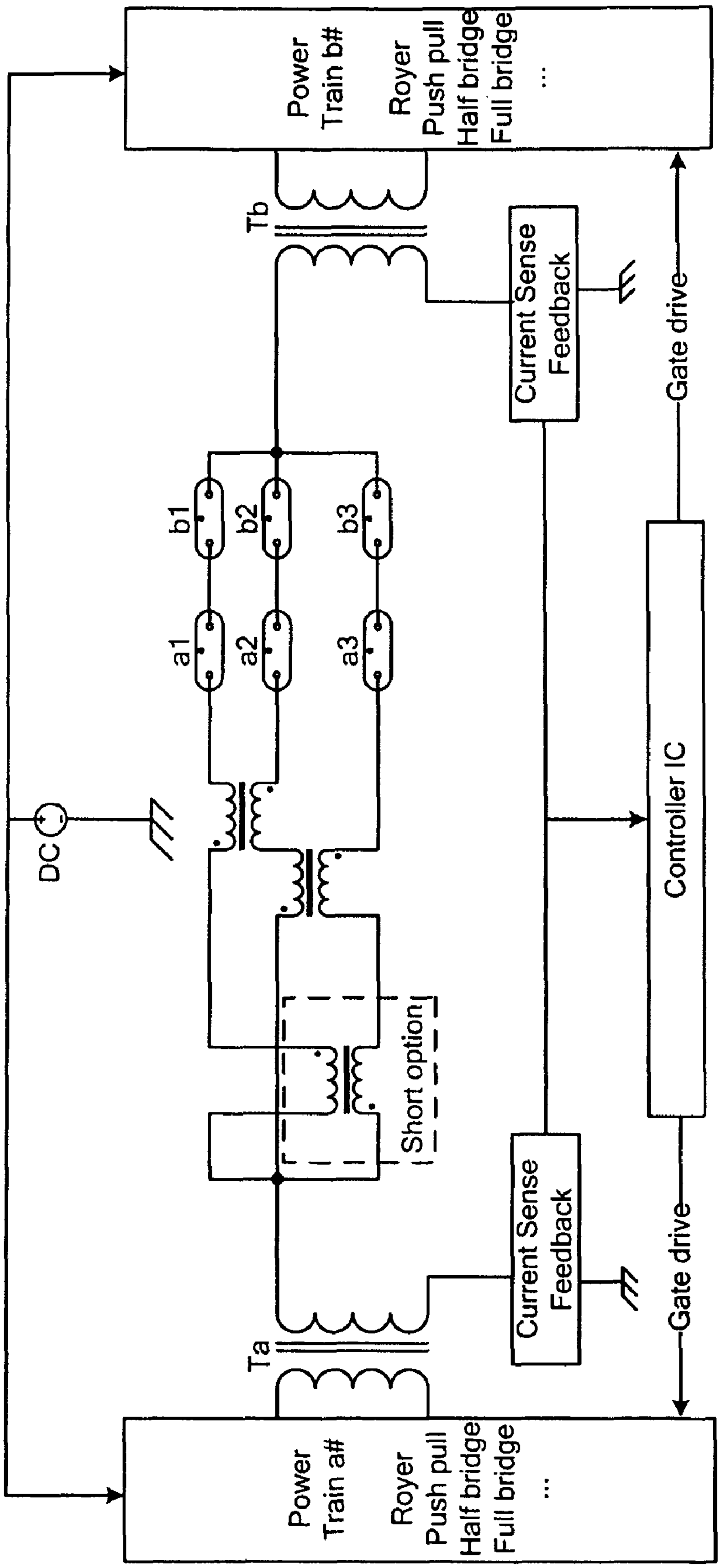

Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
Tb
Current Sense
Feedback
Gate drive
Short option
DC
b1
b2
b3
a1
a2
a3
Controller IC
Current Sense
Feedback
Gate drive
Ta
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 22



Power
Train b#
Royer
Push pull
Half bridge
Full bridge
...
Tb
Current Sense
Feedback
Gate drive
b1
b2
b3
a1
a2
a3
DC
Controller IC
Short option
Current Sense
Feedback
Gate drive
Ta
Power
Train a#
Royer
Push pull
Half bridge
Full bridge
...

FIG. 23

DRIVER SYSTEM AND METHOD FOR MULTIPLE COLD-CATHODE FLUORESCENT LAMPS AND/OR EXTERNAL-ELECTRODE FLUORESCENT LAMPS

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims priority to the Chinese Patent Application No. 200710047024.2, filed Oct. 12, 2007, which is incorporated by reference herein for all purposes. This application is related to U.S. patent application Ser. No. 11/450,904, filed Jun. 8, 2006.

STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

REFERENCE TO A "SEQUENCE LISTING," A TABLE, OR A COMPUTER PROGRAM LISTING APPENDIX SUBMITTED ON A COMPACT DISK.

Not Applicable

BACKGROUND OF THE INVENTION

The present invention is directed to integrated circuits. More particularly, the invention provides a system and method with cyclic configuration. Merely by way of example, the invention has been applied to driving multiple cold-cathode fluorescent lamps, and/or external-electrode fluorescent lamps. But it would be recognized that the invention has a much broader range of applicability.

The cold-cathode fluorescent lamp (CCFL) and external-electrode fluorescent lamp (EEFL) have been widely used to provide backlight for a liquid crystal display (LCD) module. The CCFL and EEFL often each require a high alternate current (AC) voltage such as 2 kV for ignition and normal operation. Such a high AC voltage can be provided by a CCFL driver system or an EEFL driver system. The CCFL driver system and the EEFL driver system each receive a low direct current (DC) voltage and convert the low DC voltage to the high AC voltage.

FIG. **1** is a simplified conventional driver system for CCFL and/or EEFL. The driver system **100** includes a control subsystem **110** and an AC power supply subsystem **120**. The control subsystem **110** receives a power supply voltage V_{DDA} and certain control signals. The control signals include an enabling (ENA) signal and a dimming (DIM) signal. In response, the control subsystem **110** outputs gate drive signals to the AC power supply subsystem **120**. The AC power supply subsystem **120** includes one or more MOSFET transistors and one or more power transformers, and receives a low DC voltage V_{IN}. The MOSFET transistors convert the low DC voltage V_{IN} to a low AC voltage in response to the gate drive signals. The low AC voltage is boosted to a high AC voltage V_{OUT} by the power transformers, and the high AC voltage V_{OUT} is sent to drive a system **190**. The system **190** includes one or more CCFLs and/or one or more EEFLs. The system **190** provides a current and voltage feedback to the control subsystem **110**.

As shown in FIG. **1**, the system **190** includes one or more CCFLs and/or one or more EEFLs. These lamps can be used to provide backlight for an LCD panel. For a large LCD panel,

a single-lamp backlight module often cannot provide sufficient backlighting. Consequently, a multi-lamp backlight module often is needed. For example, an LCD panel may require 20 to 40 lamps in order to provide high-intensity illumination for displaying full motion videos. From these lamps, the individual currents need to be balanced in order to maintain the display uniformity. For example, the current difference between different lamps should be maintained within a reasonable tolerance.

To balance lamp currents, some conventional techniques have been developed. For example, the conventional techniques use impedance matching schemes to build a balance controller for equalizing lamp currents. In another example, the conventional techniques use one or more common-mode chokes, which can balance the lamp currents. But these conventional systems can have various weaknesses in terms of flexibility, stability, and/or simplicity.

Hence it is highly desirable to improve techniques for multi-lamp driver system for CCFLs and/or EEFLs.

BRIEF SUMMARY OF THE INVENTION

The present invention is directed to integrated circuits. More particularly, the invention provides a system and method with cyclic configuration. Merely by way of example, the invention has been applied to driving multiple cold-cathode fluorescent lamps, and/or external-electrode fluorescent lamps. But it would be recognized that the invention has a much broader range of applicability.

According to an embodiment, the present invention provides a system for driving a plurality of cold-cathode fluorescent lamps. The system includes a subsystem configured to receive at least a DC voltage and generate a first AC voltage in response to at least the DC voltage. The system also includes a power converter configured to receive the first AC voltage and convert the first AC voltage to at least a second AC voltage. The system further includes a plurality of current balancing devices. Each of the plurality of current balancing devices is configured to receive two currents and balance the two currents. The plurality of current balancing devices includes at least a first current balancing device, a second current balancing device, and a third current balancing device. In addition, the system includes a plurality of lamp pairs. The plurality of cold-cathode fluorescent lamp pairs includes at least a first pair, a second pair, and a third pair. The first pair, the second pair, and the third pair are in a parallel configurations. The first pair is associated with a first current. The second pair is associated with a second current. The third pair is associated with a third current. The first current balancing device is configured to balance the first current and the second current. The second current balancing device is configured to balance the first current and the third current. The third current balancing device is configured to balance the third current and the second current.

According to another embodiment, the present invention provides a system for driving a plurality of cold-cathode fluorescent lamps. The system includes a first power converter configured to receive the a first AC voltage and convert the first AC voltage to at least a second AC voltage. In addition, the system includes a second power converter configured to receive the a third AC voltage and convert the third AC voltage to at least a fourth AC voltage. The system further includes a current sensing component electrically coupled to the fist power converter, the current sensor being configured to provide a signal. The system also includes a controller being configured to receive the signal. Furthermore, the system includes a plurality of current balancing devices, each of the plurality of current balancing devices being configured to receive two currents and balance the two currents. The plurality of current balancing devices includes at least a first current balancing device, a second current balancing device, and a third current balancing device. The system also includes a plurality of lamp pairs. The plurality of lamp pairs including at least a first pair, a second pair, and a third pair. The first pair, the second pair, and the third pair are in a parallel configurations. The first pair is associated with a first current. The second pair is associated with a second current. The third pair is associated with a third current. The first current balancing device is configured to balance the first current and the second current. The second current balancing device is configured to balance the first current and the third current. The third current balancing device is configured to balance the third current and the second current.

According to yet another embodiment, the present invention provides a system for driving a plurality of cold-cathode fluorescent lamps. The system includes a first power converter configured to receive the a first AC voltage and convert the first AC voltage to at least a second AC voltage. The system additionally includes a second power converter configured to receive the a third AC voltage and convert the third AC voltage to at least a fourth AC voltage. The system also includes a first current sensing component electrically coupled to the first power converter. The first current sensor is configured to provide a first feedback signal. The system additionally includes a second current sensing component electrically coupled to the second power converter, the second current sensing component being configured to provide a second feedback signal. In addition, the system includes a plurality of current balancing devices, each of the plurality of current balancing devices being configured to receive two currents and balance the two currents. The plurality of current balancing devices includes at least a first current balancing device, a second current balancing device, and a third current balancing device. Furthermore, the system includes a plurality of lamp pairs which includes at least a first pair, a second pair. The first pair, the second pair, and the third pair are in parallel configurations. The first pair is associated with a first current. The second pair is associated with a second current. The third pair is associated with a third current. The first current balancing device is configured to balance the first current and the second current. The second current balancing device is configured to balance the first current and the third current. The third current balancing device is configured to balance the third current and the second current.

According to yet another embodiment, the present invention provides a system for driving a plurality of cold-cathode fluorescent lamps. The system includes a first power converter configured to receive a first AC voltage and convert the first AC voltage to at least a second AC voltage. The system also includes a second power converter configured to receive a third AC voltage and convert the third AC voltage to at least a fourth AC voltage. The system also includes a third power converter configured to receive a first AC voltage and convert the first AC voltage to at least a fifth AC voltage. The system additionally includes a fourth power converter configured to receive a third AC voltage and convert the first AC voltage to at least a second AC voltage. The system also includes a plurality of current balancing devices, each of the plurality of current balancing devices being configured to receive two currents and balance the two currents. The plurality of current balancing devices includes at least a first current balancing device, a second current balancing device, and a third current balancing device. The system also includes a plurality of lamp pairs, the plurality of lamp pairs including at least a first pair, a second pair, a third pair, and a fourth pair. The first pair and the second pair are coupled to the first and the second power converters, the first pair and the second pair being in a parallel configuration. The third pair and the fourth pair are coupled to the third and the fourth power converters, the third pair and the fourth pair being in a parallel configuration. The first current balancing device is configured to balance the first pair and the second pair. The second current balancing device is configured to balance the third and the fourth pairs.

Many benefits are achieved by way of the present invention over conventional techniques. For example, some embodiments of the present invention provide a driver system that can balance currents between or among any number of lamps. Certain embodiments of the present invention provide a configuration in which only one or two inductive windings are in series with each lamp between the secondary winding of the transformer and the ground voltage. For example, the one or two inductive windings belong to one or two current balance chokes respectively. In another example, the currents flowing through at least majority of the lamps go through same types of circuit components. Some embodiments of the present invention provide great flexibility to the design and manufacturing of multi-lamp driver system. Certain embodiments of the present invention can improve stability and reliability of a multi-lamp driver system. Some embodiments of the present invention can simplify processes and lower costs for making a multi-lamp driver system. Certain embodiments of the present invention can balance both the currents flowing into some lamps and the currents flowing out of certain lamps. Some embodiments of the present invention can improve current balancing of a multi-lamp driver system by eliminating or reducing adverse effects by stray conductance or parasitic capacitance of the lamps. Certain embodiments of the present invention can provide current balancing to lamps driven by different transformers using cyclic current balance schemes. Some embodiments of the present invention can improve brightness uniformity on an LCD screen lit by a plurality of lamps that are driven by one or more transformers. According to a specific embodiment, the present invention provides a cost effective solution to balancing currents. For example, for N number lamps, only N/2 (or N/2-1) number of current balancing chokes is needed. Depending upon the embodiment, one or more of these benefits may be achieved. These and other benefits will be described in more detail throughout the present specification and more particularly below.

Various additional objects, features and advantages of the present invention can be more fully appreciated with reference to the detailed description and the accompanying drawings that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified conventional driver system for CCFL and/or EEFL;

FIG. **2** is a simplified driver system according to an embodiment of the present invention;

FIG. **3** is a simplified driver system according to another embodiment of the present invention;

FIG. **4** is a simplified driver system according to yet another embodiment of the present invention;

FIG. **5** is a simplified driver system according to yet another embodiment of the present invention;

FIG. **6** is a simplified driver system according to yet another embodiment of the present invention;

FIG. **7** is a simplified driver system **300** according to yet another embodiment of the present invention.

FIG. **8** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **9** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **10** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **11** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **12** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **13** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **14** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **15** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **16** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **17** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **18** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **19** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **20** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **21** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **22** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

FIG. **23** is a simplified diagram illustrating a driver system according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to integrated circuits. More particularly, the invention provides a system and method with cyclic configuration. Merely by way of example, the invention has been applied to driving multiple cold-cathode fluorescent lamps, and/or external-electrode fluorescent lamps. But it would be recognized that the invention has a much broader range of applicability.

For multiple cold-cathode fluorescent lamps and/or external-electrode fluorescent lamps, current balancing often is needed in order to provide uniform brightness over a LCD panel. But the current balancing can be difficult to achieve. For example, the negative operating impedance and positive current-temperature characteristics of a lamp can accelerate current imbalance and eventually drive the multi-lamp backlight module into a runaway situation. The multi-lamp backlight module includes a plurality of lamps parallel to the same driving source. In another example, unmatched parasitic parameters of the lamps, especially the parasitic capacitance, can exacerbate the current imbalance. In yet another example, cross-coupling between lamps may also contribute to the current imbalance.

As discussed above, there are conventional techniques for balancing lamp currents, but these conventional techniques have various weaknesses. For example, some conventional techniques can work for only two lamps driven by the same power transformer. In another example, certain conventional technique use a pyramid topology for stacking common-mode chokes as the number of lamps increases. The pyramid structure can make the multi-lamp driver system unstable and can complicate the layout of printed circuit board (PCB).

In yet another example, certain conventional techniques use an increasing number of inductors as the number of lamps

increases. These inductors are parts of the balance chokes, and are in series with each other. To achieve current balance, the inductance of each balance choke should equal to its mutual inductance because the voltage across the series of the inductors needs to equal zero. These constraints on the balance chokes may limit applications of the corresponding conventional techniques.

FIG. **2** is a simplified driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The driver system **200** includes a power and control subsystem **210**, a power converter **220**, the plurality of capacitors **230**, one or more current balance chokes **240**, one or more current balance chokes **250**, a current sensing feedback component **260**, and a voltage supply **270**. Although the above has been shown using a selected group of components for the system **200**, there can be many alternatives, modifications, and variations. For example, some of the components may be expanded and/or combined. Other components may be inserted to those noted above. Depending upon the embodiment, the arrangement of components may be interchanged with others replaced. For example, the system **200** is used to regulate a plurality of cold-cathode fluorescent lamps and/or external-electrode fluorescent lamps, such as a plurality of lamps **290**. Further details of these components are found throughout the present specification and more particularly below.

The power and control subsystem **210** receives a voltage **272** from the voltage supply **270**. For example, the voltage **272** is a DC voltage. In another example, the voltage **272** is equal to 5 volts. In response, the power and control subsystem **210** generates and provides an AC voltage **212** to the power converter **220**.

According to an embodiment, the power and control subsystem **210** also receives certain control signals. For example, the control signals include an enabling (ENA) signal and a dinning (DIM) signal. In response, the power and control subsystem **210** generates one or more gate drive signals. Additionally, the power and control subsystem **210** includes one or more MOSFET transistors. These MOSFET transistors convert the voltage **272** to the AC voltage **212** in response to the one or more gate drive signals. According to another embodiment, the voltage supply **270** can use various types of configurations, such as Royer, push-pull, half-bridge, and/or full bridge.

The power converter **220** receives the AC voltage **212** and outputs an AC voltage **222** to the plurality of capacitors **230**. According to one embodiment, the power converter **220** is a transformer. For example, the transformer includes a primary winding and a secondary winding. The primary winding receives the AC voltage **212** from the power and control subsystem **210**, and the secondary winding outputs the AC voltage **222** to the one or more capacitors **230**. For example, the secondary winding of the transformer has a much larger number of turns than the primary winding. According to another embodiment, the peak-to-peak amplitude of the AC voltage **222** is larger than the peak-to-peak amplitude of the AC voltage **212**.

The plurality of capacitors **230** includes capacitors $C_{230,\ 2\times1-1}$, $C_{230,\ 2\times1}$, . . . , $C_{230,\ 2\times m-1}$, $C_{230,\ 2\times m}$, . . . , $C_{230,\ 2\times n-1}$, $C_{230,\ 2\times n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n. In one embodiment, each capacitor includes two capacitor plates. One of these two capacitor plates receives the AC voltage **222**, and the other of these two capacitor plates is coupled to the one or more current balance chokes **240**.

The one or more current balance chokes **240** include current balance chokes $B_{240,1}, B_{240,2}, \ldots, B_{240,m}, \ldots, B_{240,n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n. For example, each current balance choke is a common-mode choke. In another example, each current balance choke is a balun choke. In yet another example, each current balance choke includes a magnetic core and two windings. Each of these two windings are wound on the magnetic core. According to an embodiment, one of these two windings is coupled to a capacitor plate of a capacitor, and the other of these two windings is coupled to a capacitor plate of another capacitor. For example, the current balance choke $B_{240,m}$ is coupled to capacitors $C_{230,2\times m-1}$ and $C_{230,2\times m}$.

The one or more current balance chokes **250** include current balance chokes $B_{250,1}, B_{250,2}, \ldots, B_{250,m}, \ldots, B_{250,n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n. For example, each current balance choke is a common-mode choke. In another example, each current balance choke is a balun choke. In yet another example, each current balance choke includes a magnetic core and two windings. Each of these two windings are wound on the magnetic core. According to an embodiment, one winding for the current balance choke $B_{250,1}$ is coupled to the current sensing feedback component **260**, and the other winding for the current balance choke $B_{250,1}$ is coupled to a predetermined voltage level, such as the ground voltage. According to another embodiment, both windings for the current balance choke $B_{250,m}$ other than $B_{250,1}$ are coupled to a predetermined voltage level, such as the ground voltage.

The current sensing feedback component **260** provides a current sensing signal **262** to the power and control subsystem **210**. For example, the power and control subsystem **210** uses the current sensing signal **262** to regulate the current flowing into and/or out of each of the plurality of lamps **290**. In another example, the power and control subsystem **210** includes a PWM controller whose output pulse width is adjusted in accordance with the current sensing signal **262**.

As discussed above, the system **200** is used to regulate the plurality of lamps **290** according to an embodiment of the present invention. For example, the plurality of lamps **290** includes one or more cold-cathode fluorescent lamps, and/or one or more external-electrode fluorescent lamps. In another example, the plurality of lamps **290** includes lamps $L_{290,2\times1-1}, L_{290,2\times1}, \ldots, L_{290,2\times m-1}, L_{290,2\times m}, \ldots, L_{290,2\times n-1}, L_{290,2\times n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n.

In one embodiment, each lamp includes two terminals. For example, one of the two terminals, e.g., a high-voltage terminal, is coupled to one winding of one of the one or more current balance chokes **240**, and the other of the two terminals, e.g., a low-voltage terminal, is coupled to one winding of one of the one or more current balance chokes **250**. In one embodiment, one winding of the current balance choke $B_{240,m}$ is coupled to one terminal of Lamp $L_{290,2\times m-1}$, and the other winding of the current balance choke $B_{240,m}$ is coupled to one terminal of Lamp $L_{290,2\times m}$. In another embodiment, if m is larger than 1 , one winding of the current balance choke $B_{250,m}$ is coupled to one terminal of Lamp $L_{290,2\times(m-1)}$, and the other winding of the current balance choke $B_{250,m}$ is coupled to one terminal of Lamp $L_{290,2\times m-1}$. In yet another embodiment, one winding of the current balance choke $B_{250,1}$ is coupled to one terminal of Lamp $L_{290,2\times n}$, and the other winding of the current balance choke $B_{250,1}$ is coupled to one terminal of Lamp $L_{290,2\times1-1}$.

In another embodiment, the connections between the plurality of lamps **290** and the current balance chokes **240** and **250** are arranged in a cyclic configuration. For example, the high-voltage terminal of Lamp $L_{290,2\times m-1}$ and the high-voltage terminal for Lamp $L_{290,2\times m}$ are connected to the same current balance choke $B_{240,m}$. The current balance choke $B_{240,m}$ can make the currents flowing into the high voltage terminals of the Lamps $L_{290,2\times m-1}$ and $L_{290,2\times m}$ to be the same. In another example, if m is larger than 1, the low-voltage terminal of Lamp $L_{290,2\times(m-1)}$ and the low-voltage terminal of Lamp $L_{290,2\times m-1}$ are connected to the same current balance choke $B_{250,m}$. The current balance choke $B_{250,m}$ can make the currents flowing out of the low voltage terminals of the Lamps $L_{290,2\times(m-1)}$ and $L_{290,2\times m-1}$ to be the same. In yet another example, the low-voltage terminal of Lamp $L_{290,2\times n}$, and the low-voltage terminal of Lamp $L_{290,2\times1-1}$ are coupled to the same current balance choke $B_{250,1}$. The current balance choke $B_{250,1}$ can make the currents flowing out of the low voltage terminals of the Lamps $L_{290,2\times n}$ and $L_{290,2\times1-1}$ to be the same. In yet another embodiment, the system **200** can make currents flowing through the plurality of lamps **290** the same if a current flowing into a high-terminal of a lamp is substantially the same as another current flowing out of a low-voltage terminal of the same lamp.

As discussed above and further emphasized here, FIG. **2** is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. In one embodiment, the power and control subsystem **210** receives a voltage sensing signal, in addition to or instead of the current sensing signal **262**. In another embodiment, the current sensing signal **262** represents the current from any single lamp selected from the plurality of lamps **290**. In yet another embodiment, the current sensing signal **262** represents the total current of some or all of the plurality of lamps **290**, and the total current can be regulated by the power and control subsystem **210**.

According to another embodiment, the system **200** is used to regulate a plurality of lamps **290** including an odd number of lamps. For example, the plurality of lamps **290** includes lamps $L_{290,2\times1-1}, L_{290,2\times1}, \ldots, L_{290,2\times m-1}, L_{290.2\times m}, \ldots$, and $L_{290,2\times n-1}$. Additionally, the plurality of capacitors **230** includes capacitors $C_{230,2\times1-1}, C_{230,2\times1}, \ldots, C_{230,2\times m-1}, C_{230,2\times m}, \ldots, C_{230,2\times n-1}$. Moreover, the one or more current balance chokes **240** include current balance chokes $B_{240,1}, B_{240,2}, \ldots, B_{240,n-1}$. Also, the one or more current balance chokes **250** include current balance chokes $B_{250,1}, B_{250,2}, \ldots, B_{250,m}, \ldots, B_{250,n}$. n is an integer larger than 1, and m is an integer equal to or larger than 1,and is equal to or smaller than n. In one embodiment, the high-voltage terminal of Lamp $L_{290,2\times n-1}$ is coupled to a capacitor plate of the capacitor $C_{230,2\times n-1}$. In another embodiment, the low-voltage terminal of Lamp $L_{290,2\times n-1}$, and the low-voltage terminal of Lamp $L_{290,2\times1-1}$ are coupled to the same current balance choke $B_{250,1}$. The current balance choke $B_{250,1}$ can make the currents flowing out of the low voltage terminals of the Lamps $L_{290,2\times n-1}$ and $L_{290,2\times1-1}$ to be the same. In yet another embodiment, the current balance choke $B_{250,1}$ and the low-voltage terminal of Lamp $L_{290,2\times(n-1)}$ are coupled to the current balance choke $B_{250,n}$. The current balance choke $B_{250,1}$ can make the currents flowing out of the low voltage terminals of the Lamps $L_{290,2\times n-1}$ and $L_{290,2\times1-1}$ to be the same. For example, the current from Lamp $L_{290,2\times n-1}$ flows through one winding of the current balance choke $B_{250,1}$ and then flow through one winding of the current balance choke $B_{250,n}$. Accordingly, the current balance choke $B_{250,n}$ can make the currents flowing out of the low voltage terminals of the Lamps $L_{290,2\times(n-1)}$ and $L_{290,2\times n-1}$ to be the same.

FIG. **3** is a simplified driver system according to another embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The driver system **300** includes a power and control subsystem **310**, a power converter **320**, the plurality of capacitors **330**, one or more current balance chokes **340**, one or more current balance chokes **350**, a current sensing feedback component **360**, and a voltage supply **370**. Although the above has been shown using a selected group of components for the system **300**, there can be many alternatives, modifications, and variations. For example, some of the components may be expanded and/or combined. Other components may be inserted to those noted above. Depending upon the embodiment, the arrangement of components may be interchanged with others replaced. For example, the system **300** is used to regulate a plurality of cold-cathode fluorescent lamps and/or external-electrode fluorescent lamps, such as a plurality of lamps **390**. Further details of these components are found throughout the present specification and more particularly below.

The power and control subsystem **310** receives a voltage **372** from the voltage supply **370**. For example, the voltage **372** is a DC voltage. In another example, the voltage **372** is equal to 5 volts. In response, the power and control subsystem **310** generates and provides an AC voltage **312** to the power converter **320**.

According to an embodiment, the power and control subsystem **310** also receives certain control signals. For example, the control signals include an enabling (ENA) signal and a dimming (DIM) signal. In response, the power and control subsystem **310** generates one or more gate drive signals. Additionally, the power and control subsystem **310** includes one or more MOSFET transistors. These MOSFET transistors convert the voltage **372** to the AC voltage **312** in response to the one or more gate drive signals. According to another embodiment, the voltage supply **370** can use various types of configurations, such as Royer, push-pull, half-bridge, and/or full bridge.

The power converter **320** receives the AC voltage **312** and outputs an AC voltage **322** to the plurality of capacitors **330**. According to one embodiment, the power converter **320** is a transformer. For example, the transformer includes a primary winding and a secondary winding. The primary winding receives the AC voltage **312** from the power and control subsystem **310**, and the secondary winding outputs the AC voltage **322** to the one or more capacitors **330**. For example, the secondary winding of the transformer has a much larger number of turns than the primary winding. According to another embodiment, the peak-to-peak amplitude of the AC voltage **322** is larger than the peak-to-peak amplitude of the AC voltage **312**.

The plurality of capacitors **330** includes capacitors $C_{330,2\times1-1}$, $C_{330,2\times1}$, . . . , $C_{330,2\times m-1}$, $C_{330,2\times m}$, . . . , $C_{330,2\times n-1}$, $C_{330,2\times n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n. In one embodiment, each capacitor includes two capacitor plates. One of these two capacitor plates receives the AC voltage **322**.

The one or more current balance chokes **340** include current balance chokes $B_{340,1}$, $B_{340,2}$, . . . , $B_{340,m}$, . . . , $B_{340,n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n. For example, each current balance choke is a common-mode choke. In another example, each current balance choke is a balun choke. In yet another example, each current balance choke includes a magnetic core and two windings. Each of these two windings are wound on the magnetic core.

The one or more current balance chokes **350** include current balance chokes $B_{350,1}$, $B_{350,2}$, . . . , $B_{350,m}$, . . . , $B_{350,n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n. For example, each current balance choke is a common-mode choke. In another example, each current balance choke is a balun choke. In yet another example, each current balance choke includes a magnetic core and two windings. Each of these two windings are wound on the magnetic core. According to an embodiment, one winding for the current balance choke $B_{350,1}$ is coupled to the current sensing feedback component **360**, and the other winding for the current balance choke $B_{350,1}$ is coupled to a predetermined voltage level, such as the ground voltage. According to another embodiment, both windings for the current balance choke $B_{250,n}$ other than $B_{250,1}$ are coupled to a predetermined voltage level, such as the ground voltage.

According to an embodiment, if m is larger than 1, one winding of the current balance choke $B_{350,m}$ is coupled to one winding of the current balance choke $B_{340,m-1}$, and the other winding of the current balance choke $B_{350,m}$ is coupled to one winding of the current balance choke $B_{340,m}$. According to another embodiment, one winding of the current balance choke $B_{350,1}$ is coupled to one winding of the current balance choke $B_{340,n}$, and the other winding of the current balance choke $B_{350,1}$ is coupled to one winding of the current balance choke $B_{340,1}$.

The current sensing feedback component **360** provides a current sensing signal **362** to the power and control subsystem **310**. For example, the power and control subsystem **310** uses the current sensing signal **362** to regulate the current flowing into and/or out of each of the plurality of lamps **390**. In another example, the power and control subsystem **310** includes a PWM controller whose output pulse width is adjusted in accordance with the current sensing signal **362**.

As discussed above, the system **300** is used to regulate the plurality of lamps **390** according to an embodiment of the present invention. For example, the plurality of lamps **390** includes one or more cold-cathode fluorescent lamps, and/or one or more external-electrode fluorescent lamps. In another example, the plurality of lamps **390** includes lamps $L_{390,2\times1-1}$, $L_{390,2\times1}$, . . . , $L_{390,2\times m-1}$, $L_{390,2\times m}$, . . . , $L_{390,2\times n-1}$, $L_{390,2\times n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n.

In one embodiment, each lamp includes two terminals. For example, one of the two terminals, e.g., a high-voltage terminal, is coupled to one capacitor plate of one of the plurality of capacitors **330**, and the other of the two terminals, e.g., a low-voltage terminal, is coupled to one winding of one of the one or more current balance chokes **340**. In another example, the high-voltage terminal of Lamp $L_{390,2\times m-1}$ is coupled to the capacitor $C_{330,2\times m-1}$, and the high-voltage terminal of Lamp $L_{390,2\times m}$ is coupled to the capacitor $C_{330,2\times m}$. Additionally, the low-voltage terminals of Lamps $L_{390,2\times m-1}$ and $L_{390,2\times m}$ are coupled to the current balance choke $B_{340,m}$.

In another embodiment, the connections among the plurality of lamps **390**, the current balance chokes **340**, and the current balance chokes **350** are arranged in a cyclic configuration. For example, the current from low-voltage terminal of Lamp $L_{390,2\times m-1}$ flows through one winding of the current balance choke $B_{340,m}$, and one winding of the current balance choke $B_{350,m}$. In another example, if m is smaller than n, the current from low-voltage terminal of Lamp $L_{390, 2\times m}$ flows through one winding of the current balance choke $B_{340,m}$, and one winding of the current balance choke $B_{350, m+1}$. In yet another example, if m is equal to n, the current from low-voltage terminal of Lamp $L_{390, 2\times n}$ flows through one winding of the current balance choke $B_{340, m}$, and one winding of the current balance choke $B_{350,1}$. In yet another embodiment, the system **300** can make currents flowing from the plurality of lamps **390** the same as shown in FIG. **3**.

As discussed above and further emphasized here, FIG. **3** is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. In one embodiment, the power and control subsystem **310** receives a voltage sensing signal, in addition to or instead of the current sensing signal **362**. In another embodiment, the current sensing signal **362** represents the current from any single lamp selected from the plurality of lamps **390**. In yet another embodiment, the current sensing signal **362** represents the total current of some or all of the plurality of lamps **390**, and the total current can be regulated by the power and control subsystem **310**.

According to another embodiment, the system **300** is used to regulate a plurality of lamps **390** including an odd number of lamps. For example, the plurality of lamps **390** includes lamps $L_{390, 2\times 1-1}, L_{390, 2\times 1}, \ldots, L_{390, 2\times m-1}, L_{390, 2\times m}, \ldots$, and $L_{390, 2\times n-1}$. Additionally, the plurality of capacitors **330** includes capacitors $C_{330, 2\times 1-1}, C_{330, 2\times 1}, \ldots, C_{330, 2\times m-1}, C_{330, 2\times m}, \ldots, C_{330, 2\times n-1}$. Moreover, the one or more current balance chokes **340** include current balance chokes $B_{340, 1}, B_{340, 2}, \ldots, B_{340, m}, \ldots, B_{340, n-1}$. Also, the one or more current balance chokes **350** include current balance chokes $B_{350,1}, B_{350,2}, \ldots, B_{350,m}, \ldots, B_{350,n}$. n is an integer larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n. For example, if m is smaller than n, the current from low-voltage terminal of Lamp $L_{390, 2\times m-1}$ flows through one winding of the current balance choke $B_{340,m}$, and one winding of the current balance choke $B_{350,m}$. Additionally, the current from the low-voltage terminal of Lamp $L_{390, 2\times n-1}$ flows through one winding of the current balance choke $B_{350, 1}$, and the current from the low-voltage terminal of Lamp $L_{390, 1}$ flows through one winding of the current balance choke $B_{340, 1}$ and one winding of the current balance choke $B_{350,1}$. Accordingly, the current balance choke $B_{350, 1}$ can make currents from the low-voltage terminal of Lamp $L_{390, 2\times n-1}$ and the low-voltage terminal of Lamp $L_{390,1}$ the same.

In another example, the current from the low-voltage terminal of Lamp $L_{390, 2\times(n-1)}$ flows through one winding of the current balance choke $B_{340,n-1}$ and one winding of the current balance choke $B_{350,n}$. Additionally, the current balance choke $B_{350, 1}$ and the current balance choke $B_{340,n-1}$ are coupled to the current balance choke $B_{350, n}$. Accordingly, the current balance choke $B_{350, n}$, can make the currents flowing out of the low voltage terminals of the Lamps $L_{390, 2\times(n-1)}$ and $L_{390, 2\times n-1}$ to be the same.

FIG. **4** is a simplified driver system **300** according to yet another embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in FIG. **4**, the driver system **300** is used to regulate a plurality of lamps **390** including three lamps. For example, the plurality of lamps **390** includes lamps $L_{390, 2\times 1-1}$, $L_{390, 2\times 1}$, and $L_{390, 2\times 2-1}$. Additionally, the plurality of capacitors **330** includes capacitors $C_{330, 2\times 1-1}$, $C_{330, 2\times 1}$, and $C_{330, 2\times 2-1}$. Moreover, the one or more current balance chokes **340** include the current balance choke $B_{340, 1}$. Also, the one or more current balance chokes **350** include current balance chokes $B_{350, 1}$ and $B_{350, 2}$. For example, the current from low-voltage terminal of Lamp $L_{390, 2\times 1-1}$ flows through one winding of the current balance choke $B_{340,1}$, and one winding of the current balance choke $B_{350,1}$. Additionally, the current from the low-voltage terminal of Lamp $L_{390, 2\times 2-1}$ flows through one winding of the current balance choke $B_{350,1}$, and the current from the low-voltage terminal of Lamp $L_{390, 1}$ flows through one winding of the current balance choke $B_{340,1}$ and one winding of the current balance choke $B_{350,1}$. Accordingly, the current balance choke $B_{350, 1}$ can make currents from the low-voltage terminal of Lamp $L_{390, 2\times 2-1}$ and the low-voltage terminal of Lamp $L_{390, 1}$ the same. In another example, the current from the low-voltage terminal of Lamp $L_{390, 2}$ flows through one winding of the current balance choke $B_{340, 1}$ and one winding of the current balance choke $B_{350, 2}$. Additionally, the current balance choke $B_{350, 1}$ and the current balance choke $B_{340, 1}$ are coupled to the current balance choke $B_{350, 2}$. Accordingly, the current balance choke $B_{350, 2}$ can make the currents flowing out of the low voltage terminals of the Lamps $L_{390, 2}$ and $L_{390, 3}$ to be the same.

FIG. **5** is a simplified driver system according to yet another embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The driver system **500** includes a power and control subsystem **510**, a power converter **520**, the plurality of capacitors **530**, one or more current balance chokes **540**, one or more current balance chokes **550**, a current sensing feedback component **560**, and a voltage supply **570**. Although the above has been shown using a selected group of components for the system **500**, there can be many alternatives, modifications, and variations. For example, some of the components may be expanded and/or combined. Other components may be inserted to those noted above. Depending upon the embodiment, the arrangement of components may be interchanged with others replaced. For example, the system **500** is used to regulate a plurality of cold-cathode fluorescent lamps and/or external-electrode fluorescent lamps, such as a plurality of lamps **590**. Further details of these components are found throughout the present specification and more particularly below.

The power and control subsystem **510** receives a voltage **572** from the voltage supply **570**. For example, the voltage **572** is a DC voltage. In another example, the voltage **572** is equal to 5 volts. In response, the power and control subsystem **510** generates and provides an AC voltage **512** to the power converter **520**.

According to an embodiment, the power and control subsystem **510** also receives certain control signals. For example, the control signals include an enabling (ENA) signal and a dimming (DIM) signal. In response, the power and control subsystem **510** generates one or more gate drive signals. Additionally, the power and control subsystem **510** includes one or more MOSFET transistors. These MOSFET transistors convert the voltage **572** to the AC voltage **512** in response to the one or more gate drive signals. According to another embodiment, the voltage supply **570** can use various types of configurations, such as Royer, push-pull, half-bridge, and/or full bridge.

The power converter **520** receives the AC voltage **512** and outputs an AC voltage **522** to the plurality of capacitors **530**. According to one embodiment, the power converter **520** is a transformer. For example, the transformer includes a primary winding and a secondary winding. The primary winding receives the AC voltage **512** from the power and control subsystem **510**, and the secondary winding outputs the AC voltage **522** to the one or more capacitors **530**. For example, the secondary winding of the transformer has a much larger number of turns than the primary winding. According to another embodiment, the peak-to-peak amplitude of the AC voltage **522** is larger than the peak-to-peak amplitude of the AC voltage **512**.

The plurality of capacitors **530** includes capacitors $C_{530,\ 2\times 1-1}$, $C_{530,\ 2\times 1}$, . . . , $C_{530,\ 2\times m-1}$, $C_{530,\ 2\times m}$, . . . , $C_{530,\ 2\times n-1}$, $C_{530,\ 2\times n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n. In one embodiment, each capacitor includes two capacitor plates. One of these two capacitor plates receives the AC voltage **522**, and the other of these two capacitor plates is coupled to the one or more current balance chokes **540**.

The one or more current balance chokes **540** include current balance chokes $B_{540,\ 1}$, $B_{540,\ 2}$, . . . , $B_{540,\ m}$, . . . , $B_{540,\ n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n. For example, each current balance choke is a common-mode choke. In another example, each current balance choke is a balun choke. In yet another example, each current balance choke includes a magnetic core and two windings. Each of these two windings are wound on the magnetic core. According to an embodiment, one of these two windings is coupled to a capacitor plate of a capacitor, and the other of these two windings is coupled to a capacitor plate of another capacitor. For example, the current balance choke $B_{540,\ m}$ is coupled to capacitors $C_{530,\ 2\times m-1}$ and $C_{530,\ 2\times m}$.

The one or more current balance chokes **550** include current balance chokes $B_{550,\ 1}$, $B_{550,\ 2}$, . . . , $B_{550,\ m}$, . . . , $B_{550,\ n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n. For example, each current balance choke is a common-mode choke. In another example, each current balance choke is a balun choke. In yet another example, each current balance choke includes a magnetic core and two windings. Each of these two windings are wound on the magnetic core.

According to an embodiment, if m is larger than 1, one winding of the current balance choke $B_{550,\ m}$ is coupled to one winding of the current balance choke $B_{540,\ m-1}$, and the other winding of the current balance choke $B_{550,\ m}$ is coupled to one winding of the current balance choke $B_{540,\ m}$. According to another embodiment, one winding of the current balance choke $B_{550,\ 1}$ is coupled to one winding of the current balance choke $B_{540,\ n}$, and the other winding of the current balance choke $B_{550,\ 1}$ is coupled to one winding of the current balance choke $B_{540,\ 1}$.

The current sensing feedback component **560** provides a current sensing signal **562** to the power and control subsystem **510**. For example, the power and control subsystem **510** uses the current sensing signal **562** to regulate the current flowing into and/or out of each of the plurality of lamps **590**. In another example, the power and control subsystem **510** includes a PWM controller whose output pulse width is adjusted in accordance with the current sensing signal **562**.

As discussed above, the system **500** is used to regulate the plurality of lamps **590** according to an embodiment of the present invention. For example, the plurality of lamps **590** includes one or more cold-cathode fluorescent lamps, and/or one or more external-electrode fluorescent lamps. In another example, the plurality of lamps **590** includes lamps $L_{590,\ 2\times 1-1}$, $L_{590,\ 2\times 1}$, . . . , $L_{590,\ 2\times m-1}$, $L_{590,\ 2\times m}$, . . . , $L_{590,\ 2\times n-1}$, $L_{590,\ 2\times n}$. n is an integer equal to or larger than 1, and m is an integer equal to or larger than 1, and is equal to or smaller than n.

In one embodiment, each lamp includes two terminals. For example, one of the two terminals, e.g., a high-voltage terminal, is coupled to one winding of the one or more current balance chokes **550**. In another example, the low-voltage terminal of Lamp $L_{590,\ 2\times m}$ is coupled to coupled to a predetermined voltage level, such as the ground voltage. In yet another example, if m is larger than 1, the low-voltage terminal of Lamp $L_{590,\ 2\times m-1}$ is coupled to a predetermined voltage level, such as the ground voltage. In yet another example, the low-voltage terminal of Lamp $L_{390,\ 2\times 1-1}$ is coupled to the current sensing feedback component **560**.

In another embodiment, the connections among the plurality of lamps **590**, the current balance chokes **540**, and the current balance chokes **550** are arranged in a cyclic configuration. For example, the current flowing into high-voltage terminal of Lamp $L_{590,\ 2\times m}$ flows through one winding of the current balance choke $B_{540,\ m}$, and one winding of the current balance choke $B_{550,\ m}$. In another example, if m is larger than 1, the current flowing into high-voltage terminal of Lamp $L_{590,\ 2\times m-1}$ flows through one winding of the current balance choke $B_{540,\ m-1}$, and one winding of the current balance choke $B_{550,\ m}$. In yet another example, if m is equal to 1, the current flowing into high-voltage terminal of Lamp $L_{390,\ 2\times 1-1}$ flows through one winding of the current balance choke $B_{540,\ 1}$, and one winding of the current balance choke $B_{550,\ m}$. In yet another embodiment, the system **500** can make currents flowing into the plurality of lamps **590** the same as shown in FIG. **5**.

As discussed above and further emphasized here, FIG. **5** is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. In one embodiment, the power and control subsystem **510** receives a voltage sensing signal, in addition to or instead of the current sensing signal **562**. In another embodiment, the current sensing signal **562** represents the current from any single lamp selected from the plurality of lamps **590**. In yet another embodiment, the current sensing signal **562** represents the total current of some or all of the plurality of lamps **590**, and the total current can be regulated by the power and control subsystem **510**.

According to another embodiment, the system **300** is used to regulate the plurality of lamps **590** including an odd number of lamps. For example, the plurality of lamps **590** includes lamps $L_{590,\ 2\times 1-1}$, $L_{590,\ 2\times 1}$, . . . , $L_{590,\ 2\times m-1}$, $L_{590,\ 2\times m}$, . . . , and $L_{590,\ 2\times n-1}$. n is an integer larger than 1,nd m is an integer equal to or larger than 1, and is equal to or smaller than n.

FIGS. **2**, **3**, **4**, and **5** are merely examples, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. For example, the plurality of capacitors **230**, **330**, or **530** are coupled to a plurality of transformers. In another example, the plurality of transformers are used to regulate the plurality of cold-cathode fluorescent lamps and/or external-electrode fluorescent lamps, such as a plurality of lamps **290**, **390**, or **590**.

FIG. **6** is a simplified driver system **200** according to yet another embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The driver system **200** includes a power and control subsystem, a power converter, the plurality of capacitors, one or more current balance chokes, one or more current balance chokes, a current sensing feedback component, and a voltage supply. For example, the power converter includes a plurality of transformers, whose primary windings are coupled to the power and control subsystem and whose secondary windings are coupled to different capacitors selected from the plurality of capacitors.

FIG. **7** is a simplified driver system **300** according to yet another embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The driver system **300** includes a power and control subsystem, a power converter, the plurality of capacitors, one or more current balance chokes, one or more current balance chokes, a current sensing feedback component, and a voltage supply. For example, the power converter includes a plurality of transformers, whose primary windings are coupled to the power and control subsystem and whose secondary windings are coupled to different capacitors selected from the plurality of capacitors.

FIG. **8** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications.

As shown, a driver system **800** includes the following components:

1. a controller **805**;
2. power and control subsystems **810** and **815**;
3. power converters **830** and **835**;
4. current balance chokes **860**-**864**;
5. current sensing feedback component **840** and **845**;
6. a DC source **820**; and
7. lamps **850**-**857**.

Although the above has been shown using a selected group of components for the system **800**, there can be many alternatives, modifications, and variations. For example, some of the components may be expanded and/or combined. Other components may be inserted to those noted above. Depending upon the embodiment, the arrangement of components may be interchanged with others replaced. For example, the system **800** is used to regulate a plurality of cold-cathode fluorescent lamps and/or external-electrode fluorescent lamps, such as lamps **850**-**857**. Further details of these components are found throughout the present specification and more particularly below.

The power and control subsystems **810** and **815** receive a voltage from the DC source **820**. For example, the voltage is a DC voltage. In another example, the voltage is approximately 5 volts. In response, the power and control subsystems **810** and **815** generates and provides an AC voltage to the power converters **830** and **835**. According to a specific example, the performance and characteristics of the power and control subsystems are substantially matched.

According to an embodiment, the power and control subsystems **810** and **815** also receives certain control signals. For example, the control signals include an enabling (ENA) signal and a dimming (DIM) signal. In response, the power and control subsystems **810** and **815** generate one or more gate drive signals. Additionally, the power and control subsystems **810** and **815** includes one or more MOSFET transistors. These MOSFET transistors convert the DC voltage to AC voltage in response to the one or more gate drive signals. According to another embodiment, the DC source **820** can use various types of configurations, such as Royer, push-pull, half-bridge, and/or full bridge.

The power converter **830** receives the AC voltage and outputs an AC voltage to pairs of lamps. According to one embodiment, the power converter **830** is a transformer. For example, the transformer includes a primary winding and a secondary winding. The primary winding receives the AC voltage from the power and control subsystem **810**, and the secondary winding outputs the AC voltage to the lamps. For example, the secondary winding of the transformer has a much larger number of turns than the primary winding.

Similarly, the power converter **835** receives the AC voltage and outputs an AC voltage to pairs of lamps. According to one embodiment, the power converter **835** is a transformer. For example, the transformer includes a primary winding and a secondary winding. The primary winding receives the AC voltage from the power and control subsystem **815**, and the secondary winding outputs the AC voltage to the lamps. For example, the secondary winding of the transformer has a much larger number of turns than the primary winding. As shown in FIG. **8**, the power converters **830** and **835** are connected the two opposite ends of each lamp pairs. For example, the lamp pairs that includes the lamps **850** and **851** are connected to the two power converters at the opposite ends. In a specific embodiment, currents from the power converters **815** and **810** are different by 180 degree in phase.

As shown in FIG. **8**, each of the current balancing choke is used to balance the current between two lamp pairs. Merely by of an example, the choke **861** is used to balance the lamp pair that includes lamps **850** and **851** with the lamp pair that includes lamps **852** and the **853**. Similarly, the choke **864** is used to balance the lamp pair that includes lamps **850** and **851** with the lamp pair that includes lamps **856** and the **857**. In the similar manner, each lamp pair is balanced with two other lamp pairs. Essentially, lamp pairs are balanced among one another. In addition, each lamp in a lamp pair is balanced against each other. Depending on the application, various types of chokes may be used. For example, each current balance choke is a common-mode choke. In another example, each current balance choke is a balun choke. In yet another example, each current balance choke includes a magnetic core and two windings. Each of these two windings are wound on the magnetic core.

Lamps in the same lamp pair are connected in series. As a result, the current of lamps in the same lamp pair is essential equal to each other in magnitude. The lamps pairs are in a parallel configuration to one another, which allows current between each lamp pair to be balanced to essentially the same level by the current balancing chokes. It is to be appreciated that the configuration as shown in system **800** allows all lamps within the system to be lit by essentially the same amount of current, thereby causing all lamps to provide luminance at substantially the same level.

The current sensing feedback component **840** provides a current sensing signal to the controller **805**, which controls the power and control subsystem **810** through a gate driver. For example, the controller uses the current sensing signal to regulate the current flowing into and/or out of each of the plurality of lamps **850**-**857**. In another example, the power and control subsystem **810** includes a PWM controller whose output pulse width is adjusted by the controller **805**.

As discussed above, the system **800** is used to regulate the plurality of lamps **850**-**857** according to an embodiment of the present invention. For example, the plurality of lamps **850**-**857** includes one or more cold-cathode fluorescent lamps, and/or one or more external-electrode fluorescent lamps. In another example, the plurality of lamps **850**-**857** includes an even number of lamps configured in lamp pairs, thereby allow each two of the two lamps in a lamp pair to be balanced with each other.

In one embodiment, each lamp includes two terminals. For example, one of the two terminals, e.g., a high-voltage terminal, is coupled to one winding of one of the power converters, and the other of the two terminals, e.g., a low-voltage terminal, is coupled to one winding of one of the one or more current balance chokes.

As discussed above and further emphasized here, FIG. **8** is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. In one embodiment, the power and control subsystems **810** and **811** receive is controlled by the controller **805**. The controller **805** receives voltage sensing signals from the current sensing feedback components **840** and **845**. The current sensing signal represents the current from any single lamp selected from the plurality of lamps **850-857**. In yet another embodiment, the current sensing signal represents the total current of some or all of the plurality of lamps **850-857**, and the total current can be regulated by the power and control subsystems **810** and **815**.

According to another embodiment, the system **800** is used to regulate a plurality of lamps **850-857** including an even number of lamps. For example, the plurality of lamps **850-857**. Moreover, the one or more current balance chokes include current balance chokes **850-857**. As an example, the number of current balancing choke required is equal to N/2 (or N/2-1), whereas N is the number of lamps. In one embodiment, the high-voltage terminal of lamp **850** is coupled to the power converter **830**. In another embodiment, the low-voltage terminal of Lamp **850** is coupled to the current balance choke **861**. As explained above, there might be other variations according to the embodiment of the present invention. For example, the configuration for the lamps and the current balancing chokes may be re-arranged.

FIG. **9** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications.

As shown, a driver system **900** includes the following components:

1. a controller **905**;
2. power and control subsystems **910** and **915**;
3. power converters **931-934**;
4. current balance chokes **960-968**;
5. a current sensing feedback component **940**;
6. a DC source **920**; and
7. lamps **950-957** and **980-987**.

Although the above has been shown using a selected group of components for the system **900**, there can be many alternatives, modifications, and variations. For example, some of the components may be expanded and/or combined. Other components may be inserted to those noted above. Depending upon the embodiment, the arrangement of components may be interchanged with others replaced. For example, the system **900** is used to regulate a plurality of cold-cathode fluorescent lamps and/or external-electrode fluorescent lamps, such as lamps **950-957** and **980-987**. Further details of these components are found throughout the present specification and more particularly below.

The power and control subsystems **910** and **915** receive a voltage from the DC source **920**. For example, the voltage is a DC voltage. In another example, the voltage is approximately 5 volts. In response, the power and control subsystems **910** and **915** generates and provides an AC voltage to the power converters **930** and **935**. According to a specific example, the performance and characteristics of the power and control subsystems are substantially matched.

According to an embodiment, the power and control subsystems **910** and **915** also receives certain control signals. For example, the control signals include an enabling (ENA) signal and a dimming (DIM) signal. In response, the power and control subsystems **910** and **915** generate one or more gate drive signals. Additionally, the power and control subsystems **910** and **915** includes one or more MOSFET transistors. These MOSFET transistors convert the DC voltage to AC voltage in response to the one or more gate drive signals. According to another embodiment, the DC source **920** can use various types of configurations, such as Royer, push-pull, half-bridge, and/or full bridge.

The power converter **931** receives the AC voltage and outputs an AC voltage to pairs of lamps. According to one embodiment, the power converter **931** is a transformer. For example, the transformer includes a primary winding and a secondary winding. The primary winding receives the AC voltage from the power and control subsystem **931**, and the secondary winding outputs the AC voltage to the lamps. For example, the secondary winding of the transformer has a much larger number of turns than the primary winding.

Similarly, the other power converters (e.g., power converters **932-934**) are connected receive an AC voltage and output a different AV voltage to the lamps. Depending on the application, the system **900** may have a higher number of power converters for providing power to the lamps.

As shown in FIG. **9**, each of the current balancing choke is used to balance the current between two lamp pairs. Merely by of an example, the choke **961** is used to balance the lamp pair that includes lamps **950** and **954** with the lamp pair that includes lamps **951** and the **955**. Similarly, the choke **964** is used to balance the lamp pair that includes lamps **950** and **954** with the lamp pair that includes lamps **953** and the **957**. In the similar manner, each lamp pair is balanced with two other lamp pairs. Essentially, lamp pairs are balanced among one another. In addition, each lamp in a lamp pair is balanced against each other. Depending on the application, various types of chokes may be used. For example, each current balance choke is a common-mode choke. In another example, each current balance choke is a balun choke. In yet another example, each current balance choke includes a magnetic core and two windings. Each of these two windings are wound on the magnetic core.

Lamps in the same lamp pair are connected in series. As a result, the current of lamps in the same lamp pair is essential equal to each other in magnitude. The lamps pairs are in a parallel configuration to one another, which allows current between each lamp pair to be balanced to essentially the same level by the current balancing chokes. It is to be appreciated that the configuration as shown in system **900** allows all lamps within the system to be lit by essentially the same amount of current, thereby causing all lamps to provide luminance at substantially the same level.

As shown in FIG. **9**, four lamps pairs are grouped together to share two power converters and four current balancing chokes. It is to be appreciated such configuration is easily scalable, as the number of lamps pairs can be increased by adding groups of lamp pairs.

The current sensing feedback component **940** provides a current sensing signal to the controller **905**, which controls the power and control subsystem **810** through a gate driver. For example, the controller uses the current sensing signal to regulate the current flowing into and/or out of each of the plurality of lamps. In another example, the power and control subsystem **910** includes a PWM controller whose output pulse width is adjusted by the controller **905**.

As discussed above, the system **900** is used to regulate the plurality of lamps according to an embodiment of the present invention. For example, the plurality of lamps includes one or more cold-cathode fluorescent lamps, and/or one or more external-electrode fluorescent lamps. In another example, the plurality of lamps includes an even number of lamps configured in lamp pairs, thereby allow each two of the two lamps in a lamp pair to be balanced with each other.

In one embodiment, each lamp includes two terminals. For example, one of the two terminals, e.g., a high-voltage terminal, is coupled to one winding of one of the power converters, and the other of the two terminals, e.g., a low-voltage terminal, is coupled to one winding of one of the one or more current balance chokes.

As discussed above and further emphasized here, FIG. **9** is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. In one embodiment, the power and control subsystems **910** and **911** receive is controlled by the controller **905**. The controller **905** receives voltage sensing signals from the current sensing feedback component **940**. The current sensing signal represents the current from any single lamp selected from the plurality of lamps. In yet another embodiment, the current sensing signal represents the total current of some or all of the plurality of lamps, and the total current can be regulated by the power and control subsystems **910** and **915**.

According to another embodiment, the system **900** is used to regulate a plurality of lamps including an even number of lamps. For example, the plurality of lamps. Moreover, the one or more current balance chokes include current balance chokes. As an example, the number of current balancing choke required is equal to N/2 (or N/2-1), whereas N is the number of lamps. In one embodiment, the high-voltage terminal of lamp **850** is coupled to the power converter **931**. In another embodiment, the low-voltage terminal of Lamp **950** is coupled to the current balance choke **961**. As explained above, there might be other variations according to the embodiment of the present invention. For example, the configuration for the lamps and the current balancing chokes may be re-arranged.

FIG. **10** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, lamps in each of lamp pair are directed coupled to each other, where as current balancing chokes are coupled to one of the lamps and a power converter.

FIG. **11** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, lamps in each of lamp pair are directed coupled to each other, where as current balancing chokes are coupled to one of the lamps and a power converter. It is to be appreciated that the system as shown in FIG. **11** is easily scalable.

FIG. **12** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, lamps in each of lamp pair are directed coupled to each other, where as current balancing chokes are coupled to one of the lamps and a power converter. It is to be appreciated that the system as shown in FIG. **12** is easily scalable.

FIG. **13** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, lamps in each of lamp pair are directed coupled to each other, where as current balancing chokes are coupled to one of the lamps and a power converter. It is to be appreciated that the system as shown in FIG. **13** is easily scalable. In contrast to the system illustrated in FIG. **12**, lamps pairs are not grouped, which allows lamp pairs in the system to be balanced against one another.

FIG. **14** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, lamps in each of lamp pair are directed coupled to each other, where as current balancing chokes are coupled to one of the lamps and a power converter. It is to be appreciated that the system as shown in FIG. **14** is easily scalable.

FIG. **15** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, lamps in each of lamp pair are directed coupled to each other, where as current balancing chokes are coupled to one of the lamps and a power converter. It is to be appreciated that the system as shown in FIG. **15** is easily scalable. In contrast to the system illustrated in FIG. **12**, lamps pairs are not grouped, which allows lamp pairs in the system to be balanced against one another.

FIG. **16** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, lamps in each of lamp pair are directed coupled to each other, where as current balancing chokes are coupled to one of the lamps and a power converter.

FIG. **17** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, lamps in each of lamp pair are directed coupled to each other, where as current balancing chokes are coupled to one of the lamps and a power converter. It is to be appreciated that the system as shown in FIG. **17** is easily scalable. In contrast to the system illustrated in FIG. **12**, lamps pairs are not grouped, which allows lamp pairs in the system to be balanced against one another.

FIG. **18** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, two lamp pairs are coupled in series with each other through a current balancing chokes. Each of the lamp pairs has two lamps in parallel and coupled to the coke. It is to be appreciated that the configuration according to FIG. **18** is cost-effective, as only one current balancing choke is needed for four lamps.

FIG. **19** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, two lamp pairs are coupled in parallel with each other through a current balancing chokes. Each of the lamp pairs has two lamps in series and coupled to the coke. It is to be appreciated that the configuration according to FIG. **19** is cost-effective, as only one current balancing choke is needed for four lamps.

FIG. **20** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, two lamp pairs are coupled in parallel with each other through a current balancing chokes. Each of the lamp pairs has two lamps in series and coupled to the coke. It is to be appreciated that the configuration according to FIG. **20** is cost-effective, as only one current balancing choke is needed for four lamps.

FIG. **21** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, a total of six lamps are balanced by two or three chokes. For example, the six lamps can be viewed as three pairs, each of the pairs having two lamps in series with a choke. Depending on the application, two-choke or three-choke configurations may be used. It is to be appreciated even with two-choke configuration, current is balanced among each lamps, thereby provide current balancing in a cost-effective manner (e.g., two chokes for six lamps).

FIG. **22** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, a total of six lamps are balanced by two or three chokes. For example, the six lamps can be viewed as three pairs, each of the pairs having two lamps in series with a choke. Depending on the application, two-choke or three-choke configurations may be used. It is to be appreciated even with two-choke configuration, current is balanced among each lamps, thereby provide current balancing in a cost-effective manner (e.g., two chokes for six lamps).

FIG. **23** is a simplified diagram illustrating a driver system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown, a total of six lamps are balanced by two or three chokes. For example, the six lamps can be viewed as three pairs, each of the pairs having two lamps in series with a choke. Depending on the application, two-choke or three-choke configurations may be used. It is to be appreciated even with two-choke configuration, current is balanced among each lamps, thereby provide current balancing in a cost-effective manner (e.g., two chokes for six lamps).

According to an embodiment, the present invention provides a system for driving a plurality of cold-cathode fluorescent lamps. The system includes a subsystem configured to receive at least a DC voltage and generate a first AC voltage in response to at least the DC voltage. The system also includes a power converter configured to receive the first AC voltage and convert the first AC voltage to at least a second AC voltage. The system further includes a plurality of current balancing devices. Each of the plurality of current balancing devices is configured to receive two currents and balance the two currents. The plurality of current balancing devices includes at least a first current balancing device, a second current balancing device. In addition, the system includes a plurality of lamp pairs. The plurality of cold-cathode fluorescent lamp pairs includes at least a first pair and a second pair. The first pair, the second pair, and the third pair are in parallel configurations. The first pair is associated with a first current. The second pair is associated with a second current. The third pair is associated with a third current. The first current balancing device is configured to balance the first current and the second current. The second current balancing device is configured to balance the first current and the third current. The third current balancing device is configured to balance the third current and the second current. For example, the embodiment is illustrated according to FIG. **9**.

According to another embodiment, the present invention provides a system for driving a plurality of cold-cathode fluorescent lamps. The system includes a first power converter configured to receive the first AC voltage and convert the first AC voltage to at least a second AC voltage. In addition, the system includes a second power converter configured to receive the a third AC voltage and convert the third AC voltage to at least a fourth AC voltage. The system further includes a current sensing component electrically coupled to the first power converter, the current sensor being configured to provide a signal. The system also includes a controller being configured to receive the signal. Furthermore, the system includes a plurality of current balancing devices, each of the plurality of current balancing devices being configured to receive two currents and balance the two currents. The plurality of current balancing devices includes at least a first current balancing device, a second current balancing device. The system also includes a plurality of lamp pairs. The plurality of lamp pairs including at least a first pair, a second pair. The first pair, the second pair, and the third pair are in a parallel configurations. The first pair is associated with a first current. The second pair is associated with a second current. The third pair is associated with a third current. The first current balancing device is configured to balance the first current and the second current. The second current balancing device is configured to balance the first current and the third current. The third current balancing device is configured to balance the third current and the second current. For example, the embodiment is illustrated according to FIG. **9**.

According to yet another embodiment, the present invention provides a system for driving a plurality of cold-cathode fluorescent lamps. The system includes a first power converter configured to receive the a first AC voltage and convert the first AC voltage to at least a second AC voltage. The system additionally includes a second power converter configured to receive the a third AC voltage and convert the third AC voltage to at least a fourth AC voltage. The system also includes a first current sensing component electrically coupled to the first power converter. The first current sensor is configured to provide a first feedback signal. The system additionally includes a second current sensing component electrically coupled to the second power converter, the second current sensing component being configured to provide a second feedback signal. In addition, the system includes a plurality of current balancing devices, each of the plurality of current balancing devices being configured to receive two currents and balance the two currents. The plurality of current balancing devices includes at least a first current balancing device, a second current balancing device. Furthermore, the system includes a plurality of lamp pairs which includes at least a first pair, a second pair. The first pair, the second pair, and the third pair are in parallel configurations. The first pair is associated with a first current. The second pair is associated with a second current. The third pair is associated with a third current. The first current balancing device is configured to balance the first current and the second current. The second current balancing device is configured to balance the first current and the third current. The third current balancing device is configured to balance the third current and the second current. For example, the embodiment is illustrated according to FIG. **8**.

According to yet another embodiment, the present invention provides a system for driving a plurality of cold-cathode fluorescent lamps. The system includes a first power converter configured to receive a first AC voltage and convert the first AC voltage to at least a second AC voltage. The system also includes a second power converter configured to receive a third AC voltage and convert the third AC voltage to at least a fourth AC voltage. The system also includes a third power converter configured to receive a first AC voltage and convert the first AC voltage to at least a fifth AC voltage. The system additionally includes a fourth power converter configured to receive a third AC voltage and convert the first AC voltage to at least a second AC voltage. The system also includes a plurality of current balancing devices, each of the plurality of current balancing devices being configured to receive two currents and balance the two currents. The plurality of current balancing devices includes at least a first current balancing device, a second current balancing device, and a third current balancing device. The system also includes a plurality of lamp pairs, the plurality of lamp pairs including at least a first pair, a second pair, a third pair, and a fourth pair. The first pair and the second pair are coupled to the first and the second power converters, the first pair and the second pair being in a parallel configuration. The third pair and the fourth pair are coupled to the third and the fourth power converters, the third pair and the fourth pair being in a parallel configuration. The first current balancing device is configured to balance the first pair and the second pair. The second current balancing device is configured to balance the third and the fourth pairs. For example, the embodiment is illustrated according to FIG. **10**.

Many benefits are achieved by way of the present invention over conventional techniques. For example, some embodiments of the present invention provide a driver system that can balance currents between or among any number of lamps. Certain embodiments of the present invention provide a configuration in which only one or two inductive windings are in series with each lamp between the secondary winding of the transformer and the ground voltage. For example, the one or two inductive windings belong to one or two current balance chokes respectively. In another example, the currents flowing through at least majority of the lamps go through same types of circuit components. Some embodiments of the present invention provide great flexibility to the design and manufacturing of multi-lamp driver system. Certain embodiments of the present invention can improve stability and reliability of a multi-lamp driver system. Some embodiments of the present invention can simplify processes and lower costs for making a multi-lamp driver system. Certain embodiments of the present invention can balance both the currents flowing into some lamps and the currents flowing out of certain lamps. Some embodiments of the present invention can improve current balancing of a multi-lamp driver system by eliminating or reducing adverse effects by stray conductance or parasitic capacitance of the lamps. Certain embodiments of the present invention can provide current balancing to lamps driven by different transformers using cyclic current balance schemes. Some embodiments of the present invention can improve brightness uniformity on an LCD screen lit by a plurality of lamps that are driven by one or more transformers. According to a specific embodiment, the present invention provides a cost effective solution to balancing currents. For example, for N number lamps, only N/2 (or N/2-1) number of current balancing chokes is needed. Depending upon the embodiment, one or more of these benefits may be achieved. These and other benefits will be described in more detail throughout the present specification and more particularly below.

Although specific embodiments of the present invention have been described, it will be understood by those of skill in the art that there are other embodiments that are equivalent to the described embodiments. Accordingly, it is to be understood that the invention is not to be limited by the specific illustrated embodiments, but only by the scope of the appended claims.

What is claimed is:

1. A system for driving a plurality of cold-cathode fluorescent lamps, the system comprising:

a subsystem configured to receive at least a DC voltage and generate a first AC voltage in response to at least the DC voltage;

a power converter configured to receive the first AC voltage and convert the first AC voltage to at least a second AC voltage;

a plurality of current balancing devices, each of the plurality of current balancing devices being configured to receive two currents and balance the two currents, the plurality of current balancing devices including at least a first current balancing device, a second current balancing device, and a third current balancing device; and

a plurality of lamp pairs, the plurality of lamp pairs including at least a first pair, a second pair, and a third pair;

wherein:

the first pair, the second pair, and the third pair are in a parallel configuration, the first pair being associated with a first current, the second pair being associated with a second current, the third pair being associated with a third current;

the first current balancing device is configured to balance the first current and the second current;

the second current balancing device is configured to balance the first current and the third current; and

the third current balancing device is configured to balance the third current and the second current.

2. The system of claim **1** wherein the plurality of lamps comprises cold-cathode fluorescent lamps.

3. The system of claim **1** wherein the plurality of lamps comprises an EEFL.

4. The system of claim **1** further comprising a current-sensing component for providing a feedback signal.

5. The system of claim **1** wherein the first pair includes a first lamp and a second lamp, the first lamp and the second lamp being electrically coupled in a series configuration.

6. The system of claim **1** wherein the first pair comprises the first lamp and a second lamp.

7. The system of claim **1** wherein the first current and the second current are equal in amplitude.

8. The system of claim **1** further comprising a DC power source.

9. The system of claim **1** further comprising a control component, the control component being configured to regulate the subsystem.

10. The system of claim 1 further comprising a current-sensing component for providing a feedback signal to the power converter.

11. The system of claim 1 wherein:

the first pair is characterized by a first luminance;

the second pair is characterized by a second luminance; and

the first luminance and the second luminance are substantially the same.

12. A system for driving a plurality of cold-cathode fluorescent lamps, the system comprising:

a first power converter configured to receive a first AC voltage and convert the first AC voltage to at least a second AC voltage;

a second power converter configured to receive a third AC voltage and convert the third AC voltage to at least a fourth AC voltage;

a current sensing component electrically coupled to the first power converter, the current sensing component being configured to provide a signal;

a controller being configured to receive the signal;

a plurality of current balancing devices, each of the plurality of current balancing devices being configured to receive two currents and balance the two currents, the plurality of current balancing devices including at least a first current balancing device, a second current balancing device, and a third current balancing device; and

a plurality of lamp pairs, the plurality of lamp pairs including at least a first pair, a second pair, and a third pair;

wherein:

the first pair, the second pair, and the third pair are in a parallel configuration, the first pair being associated with a first current, the second pair being associated with a second current, the third pair being associated with a third current;

the first current balancing device is configured to balance the first current and the second current;

the second current balancing device is configured to balance the first current and the third current; and

the third current balancing device is configured to balance the third current and the second current.

13. The system of claim 12 wherein the first pair includes a first lamp and a second lamp, the first current balancing device being positioned between the first lamp and the second lamp.

14. The system of claim 12 wherein the signal is associated with the first power converter.

15. The system of claim 12 wherein the current sensing component is grounded.

16. The system of claim 12 wherein the controller is configured to provide a control signal to a power train.

17. The system of claim 12 further comprising a subsystem configured to receive at least a DC voltage and generate the first AC voltage in response to at least the DC voltage.

18. The system of claim 12 wherein the second power converter is grounded.

19. The system of claim 12 further comprising a DC power source.

20. The system of claim 12 wherein the first power converter includes at least a first transformer and a second transformer.

21. The system of claim 12 wherein the first current balancing device comprises a current balance choke.

22. The system of claim 12 wherein the first pair is electrically coupled to both the first power converter and the second power converter.

23. A system for driving a plurality of cold-cathode fluorescent lamps, the system comprising:

a first power converter configured to receive a first AC voltage and convert the first AC voltage to at least a second AC voltage;

a second power converter configured to receive a third AC voltage and convert the third AC voltage to at least a fourth AC voltage;

a first current sensing component electrically coupled to the first power converter, the first current sensing component being configured to provide a first feedback signal;

a second current sensing component electrically coupled to the second power converter, the second current sensing component being configured to provide a second feedback signal;

a plurality of current balancing devices, each of the plurality of current balancing devices being configured to receive two currents and balance the two currents, the plurality of current balancing devices including at least a first current balancing device, a second current balancing device, and a third current balancing device; and

a plurality of lamp pairs, the plurality of lamp pairs including at least a first pair, a second pair, and a third pair;

wherein:

the first pair, the second pair, and the third pair are in a parallel configuration, the first pair being associated with a first current, the second pair being associated with a second current, the third pair being associated with a third current;

the first current balancing device is configured to balance the first current and the second current;

the second current balancing device is configured to balance the first current and the third current; and

the third current balancing device is configured to balance the third current and the second current.

24. The system of claim 23 wherein a first choke is positioned between the first pair and the first power converter.

25. The system of claim 23 further comprising a controller, the controller being configured to receive the first and second feedback signals.

26. The system of claim 23 wherein the first pair is electrically coupled to the first power converter and the second power converter.

27. The system of claim 23 wherein the first current and the third current are substantially equal in magnitude.

28. The system of claim 23 wherein:

the first power converter is characterized by a first phase;

the second power converter is characterized by a second phase; and

the first phase and the second phase are different by 180 degrees.

29. The system of claim 23 further including a fourth lamp pair and a fourth balancing device.

30. The system of claim 23 wherein the first balancing device comprises a choke.

31. A system for driving a plurality of cold-cathode fluorescent lamps, the system comprising:

a first power converter configured to receive a first AC voltage and convert the first AC voltage to at least a second AC voltage;

a second power converter configured to receive a third AC voltage and convert the third AC voltage to at least a fourth AC voltage;

a third power converter configured to receive the first AC voltage and convert the first AC voltage to at least a fifth AC voltage;

a fourth power converter configured to receive the third AC voltage and convert the third AC voltage to at least a sixth AC voltage;

a plurality of current balancing devices, each of the plurality of current balancing devices being configured to receive two currents and balance the two currents, the plurality of current balancing devices including at least a first current balancing device, a second current balancing device, and a third current balancing device; and

a plurality of lamp pairs, the plurality of lamp pairs including at least a first pair, a second pair, a third pair, and a fourth pair;

wherein:

the first pair and the second pair are coupled to the first power converter and the second power converter, the

first pair and the second pair being in a first parallel configuration;

the third pair and the fourth pair are coupled to the third power converter and the fourth power converter, the third pair and the fourth pair being in a second parallel configuration;

the first current balancing device is configured to balance the first pair and the second pair; and

the second current balancing device is configured to balance the third pair and the fourth pair.

32. The system of claim **31** further comprising a power system for converting a DC voltage to the first AC voltage.

33. The system of claim **31** further comprising a current sensor.

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